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CHINA REPORT

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CONTENTS (Continued)

NATIONAL DEVELOPMENTS

SCIENTIFIC AND TECHNICAL ASSOCIATIONS ACTIVE IN SEVERAL AREAS

Tianjin Party Committee Cooperates

Beijing GUANGMING RIBAO in Chinese 13 Mar 80 p 2

[Article by Wang Lihua [3769 5461 5478]]

[Text] The Tianjin Municipal Party Committee sets great store in and cherishes the work of the Tianjin Municipal Scientific and Technical Association, actively creates conditions for the development of the association's work, resolves various kinds of actual problems, and allows the association's organization to have a more and more important effect on the four modernizations.

The concern and respect of the Tianjin Party Committee for the Municipal Scientific and Technical Association is manifested in many ways. The foremost means is a specific formula and linking of circumstances for listening to their opinions. The Municipal Party Committee commonly invites responsible persons and specialists from the scientific association to attend the committee's work meetings, expanded meetings of the standing committee, and important meetings concerned with the municipal planning conference. When the secretrary of the party committee hears special reports on areas such as economics, foreign trade, or culture and education, he often allows the responsible person of the scientific association to attend. Before the municipal party committee decides on some important questions, they are careful to hear the opinions of specialists of the various societies of the association, as when First Secretary Chen Weida had a discussion with the director of the electronics society to solicit his ideas concerning the development of the Tianjin electronics industry.

Second, to fully develop the usefulness of the association, the committee often assigns it subjects or tasks. From January 1978 to the end of last year, the municipal party committee issued proposals and requirements on the work of the scientific association more than 30 times. This has been extremely instrumental in guiding the work of the association to the service of the four modernizations. Tianjin's newly established energy resources society and other organizations were established according to need after proposals were made by the municipal party committee.

Third, the municipal party committee makes every possible effort to resolve difficulties encountered by the science association in actual work. For example, scientific and technical personnel mentioned that there was no site for academic activities. The municipal party committee decided to let them convert the People's Auditorium, which was used for meetings of the municipal party committee and the municipal revolutionary committee, into a science meeting hall. This decision was enthusiastically welcomed by the scientific and technical personnel of the whole city. To strengthen the day-to-day actual work of the city's 61 societies, the party committee provided solutions for some table of organization problems concerning full-time cadres. With the concern and support of the municipal party committee, the Tianjin College of Scientific Advanced Studies and its branches in the various districts did a great deal of work in training talent, which was greatly welcomed by scientific and technical personnel.

The concern and respect of the municipal party committee for the scientific association is a great motivation for the activism of the various societies and many specialists of the association. The municipal civil engineering society organized nearly 300 specialists, professors, engineers and technicians to discuss the city's water supply and drainage, roadway communications, municipal gas supply, municipal reconstruction, and other special problems: it submitted nearly 30 proposals on broadening sources and reducing consumption of water, drainage routes, solving transportation bottlenecks, ways to develop a gas supply, and reconstructing the old districts. These proposals and minutes of the meetings were forwarded to the party committee and received the leaders' serious consideration. When the revised Tianjin municipal construction plan is formulated, some proposals will already have been adopted. "Looking at the Only Standard for Examining Truth from the Practice of Vegetable Production" and "The Occurrence and Prevention of Dry Heart Disease in Chinese Cabbage" by Liu Zongfan, deputy director of the municipal agricultural society; "Broadening the Recruitment of Talent and Raising Quality" and "Some Suggestions for Reforming Higher Education" by Professor Wu Daren; "An Appeal for Tianjin Municipal Water Conservancy" by Deputy Chief Engineer Mi Jiatong, director of the municipal water conservancy society, and ideas and suggestions from other worthwhile books have all received careful consideration by the municipal party committee and concerned departments, and some have been adopted.

Because of the concern and consideration of the municipal party committee, the work of the Tianjin Municipal Scientific Association has received a relatively great advance. They have had rather good accomplishments in academic exchanges, solving difficult problems, popularizing science, and training talent.

Beijing Restores Scientific Groups

Beijing GUANGMING RIBAO in Chinese 13 Mar 80 p 2

[Text] Scientific associations and societies were restored in 16 wards and counties of the Beijing Municipality last year. After they were restored, these associations and societies were very active in combining with actual

production and in developing activities for scholarly exchanges and popularizing science and technology. According to incomplete statistics, they organized 259 professional training sessions last year and trained more than 36,000 scientific and technical personnel and key technical personnel; they delivered 391 scholarly reports and lectures, with a total attendance of more than 55,000; and they organized 108 technical inspections.

Last year, 16 ward and county organizations of the scientific association in Xuanwu, Congwen, Dongcheng, Xicheng, Haidian, Fengtai, Shijingshan, Mentougou, Chaoyang, Daxing, Tongxian, Shunyi, Huairou, Yanqing, Miyun, and Pinggu were restored. During this period, 86 ward and county societies and 153 professional (academic) groups subordinate to the societies were restored or established.

One of the principal activities of the ward and county scientific associations and societies is the solution of actual problems in industrial and agricultural production in the immediate area and in accordance with local conditions. The Shunyi County orchard and forestry society organized an investigation into and discussion of some fruit production problems and encouraged the further extension of good varieties and new techniques. Last summer, more than 80,000 good variety stems were grafted in the county, creating the conditions for a rich harvest this year. Plum trees are long-lived and easy to care for, and with moderate care they produce as much as 6,000-7,000 jin per mou. In the past few years, the export of plums greatly increased. To encourage this work, the orchard and forestry society organized a plum judging and selected a certain variety to be the principal planting. After the meeting, more then 3,000 stems of that plum were grafted throughout the county.

The scientific and technical training activities organized by the ward and county societies were welcomed by scientific and technical personnel. The cardiovascular professional group of the Shinjingshan Ward Medical, Pharmacological, and Health Society, in coordination with local cardiovascular disease prevention work, for 1 year held a half-day a week study class for the prevention of cardiovascular disease for personnel and has already completed the curriculum on dissection, pathology, physiology, biotransformation, statistics, and some of the clinical curriculum. Through study and practice, basic level medical units in some plants and mines have already established lifesaving squads and have saved several sick people. For example, of 13 patients suffering from acute myocardial infarction at the Tegang Hospital last year, 11 were saved. Besides producing popular science lecture broadcasts on pig breeding in cooperation with the county broadcasting station, the Changping Animal Husbandry and Aquatic Products Society also presented popular science lectures on semi-mechanized pig farms and chicken farms for the technicians concerned.

Many ward and county societies have also developed an advisory and consultant's function and proposed a great many suggestions. For example, various basic level production units in Shunyi County originally had divergent understanding of the prescribed density for planting apple trees and were not planting uniformly. The county orchard and forestry society organized members to carry out an investigation in Tongxian, and they proposed a rational density standard.

Zhuzhou Scientific Advisory Groups

Beijing GUANGMING RIBAO in Chinese 13 Mar 80 p 2

[Text] Through various kinds of activities, the scientific and technical advisory group of Zhuzhou municipality in Hunan Province has forcefully promoted the development of scientific and technial affairs throughout the city.

This advisory group, established in March 1979, comprises 16 regular and deputy chief engineers, engineers, chiefs of scientific institutes, and technical core cadre. They have proposed more than 20 ideas and suggestions centering on the actual situation of Zhuzhou municipality's production and construction and scientific and technical work, assisted the municipal party committee in determining policies for the development of science and technology throughout the city and the key scientific research subjects involved, and produced results relatively quickly. At the same time, they have also done a great deal of work toward forming networks for city-wide scientific and technical work, scientific and technical intelligence, popular science activities, and large-scale precision instrument cooperation.

The advisory group took over leadership of the key scientific research subjects for the city, helped various concerned units overcome difficulties and weaknessess in technical strength, and achieved good and rapid results. When the Zhuzhou Tungsten and Molybdenum Materials Plant studied a new process of high-pressure hydrogen reduction, carrying out broad experiments at an advanced international level, they attacked the difficulties and perfected the new technique through the cooperation of the leadership and technicans of the plant with advisory group members deputy chief engineer Wang Youngqing and engineer Zhang Pingmen. In the past year, members of the advisory group have individually participated directing and completing 10 key scientific research projects, five of which reached an advanced national or international level; at the same time, they also helped in solving 12 important technical problems.

Besides this, members of the advisory group, with this unit as their base, have conducted various kinds of professional technical study classes, lectures, and reports conferences, as well as training technical personnel by making apprenticeship contracts, mutual help and study, etc.

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APPLIED SCIENCES

SUMMER ATMOSPHERIC CIRCULATION OVER EAST ASIA STUDIED

Beijing DAQI KEXUE [SCIENTIA ATMOSPHERICA SINICA] in Chinese Vol 3 No 3, Sep 79 pp 219-225

[Article by Zhu Baozhen [2612 2128 4176] and Song Zhengshan [1345 2973 1482] of the Atmospheric Physics Institute of the Chinese Academy of Sciences: "Study of Atnospheric Circulation Over East Asia in Summer"]

[Text] East Asia is situated to the east of the world's largest Eurasian continent. It has the world's highest plateau--our nation's Qinghai-Xizhang Plateau. East Asia connects with two great oceans in the east and south--the Pacific and the Indian oceans. East Asia's geographical characteristics are outstanding compared to geographical features throughout the world. Therefore this region's atmospheric circulation and the connected weather changes also have many complex and outstanding characteristics. Our nation's meteorological research workers conducted a series of studies of atmospheric circulation over East Asia in the 1950's and their work has been noticed at home and abroad. East Asia is one of the world's most famous activity zones of seasonal winds. Atmospheric circulation and weather changes in summer are more outstanding and complex and they are more important in weather forecasting. Therefore since the 1960's, studies in these aspects have increased day by day. To commemorate our great motherland's 30th founding anniversary, this article retraces the studies related to atmospheric circulation over East Asia in summer.

I. Distribution of Heat Sources in East Asia in Summer

The disposition of the sea, land and topography causes an uneven heating of the atmosphere. It affects the movement of the atmosphere. The movement in turn affects the contribution in heating the atmosphere by the sea, land and topography. Therefore heating of the atmosphere is not only determined by the sun's rays and the distribution of land and sea, but is also determined by the movement of the atmosphere itself. Thus the sources of heat must be understood in several aspects.

1. Heat Sources of Ground Surfaces

The difference between the heat of the sea and of land is mainly manifested by the equilibrium of heat on the surface of the ground. Heat is gained or lost by radiation and by heat exchange between the atmosphere and soil to maintain thermal equilibrium. If the ground surface at a certain region frequently supplies (takes) heat to (from) the atmosphere via equalization of heat, that region is called a heat source (cold source). According to calculations and data of observations compiled by the large number of observatories in our nation, a seasonal distribution of cold and heat sources and distribution of radiative equilibrium and thermal equilibrium on the ground surface of East Asia have been mapped.[1] In the summer, our nation's continental surface heating is mainly determined by the distribution of radiative equilibrium. This distribution is generally the greatest in June. It is worth noticing that calculations of thermal equilibrium show that the Qinghai-Xizhang Plateau is not only a heat source in January and December but in July, the amount of heat in the plateau can reach 6 to 7 kilocalorie/centimeter^2 · month in July. This result indicates that the heating effect of the Qinghai Xizhang Plateau upon atmospheric circulation over East Asia is a question worth special attention.

2. Heat Sources in the Free Atmosphere

The amount of thermal equilibrium of surface heat is only the thermal flux entering the entire atmosphere. Movement of the atmosphere is related to the distribution of the levels of heating and it is also closely related to the perpendicular distribution of heat. We need to know the differences in the thermal flux between different layers within the atmosphere. This means we need to understand the heat sources in the free atmosphere. These sources are determined by the radiation, condensation and heat sensitivity between the earth and the atmosphere. When the absolute heating rate of the air at a certain height above a certain locality is positive (negative), the place in the air is called the heat source (cold source).

From June to August, the lower half of the troposphere of the free atmosphere over the continent of East Asia is the heat source centered above the plateau, while over the ocean, the atmosphere within a very broad region frequently loses heat to become a cold source. The cold source of the eastern Pacific Ocean is much stronger than the cold source of the western Pacific.[2] The strongest heat source over the continent may be at the southeast of the plateau. Because the lower cushioning surface of the plateau is high, the troposphere is thin (at this point), therefore long wavelength radiation is weak but absorption of the sun's short wavelength radiation is strong. And in July, condensation and heating are especially great here.[3] Above the ocean the cold source is actually the descending region of increasing temperatures driven by the high pressures of the subtropical zone. To maintain equilibrium, the atmosphere must

undergo a cooling process. It can be derived that this is accomplished mainly by the action of radiation.

3. Heat Source at the Top of the Atmosphere

The intake and release of heat of the entire earth and atmosphere system are related to the net radiation in the entire atmosphere and earth's reflection, and actually represent the equalization of radiation at the top of the atmosphere. The radiative equilibrium of our nation's geometerological system has a very small gradient at high latitude regions (40° - 60° N) in June, and changes are slight while the gradient in plateau regions changes to a relatively greater extent.[4]

II. Maintenance of Average Circulation in Summer

In mid-summer over the northern hemisphere, there are 6 to 7 wave systems of medium circulations at 500 millibars over the subtropical zone. Stable wavelengths span about 50 to 60 degrees in longitude. The average longitudinal kinetic energy spectrum at 500 millibars along the 30°N latitude circle in each month over many years in the northern hemisphere also shows the maximum number of waves that have occurred number 6 to 7.[5] Therefore, in summer there are six to seven subtropical high pressure units. The one which affects our nation's weather is mainly the western Pacific's subtropical high pressure, while above the Qinghai-Xizhang Plateau there is a low pressure circulation. In the tropopause above the western Pacific the subtropical high pressure weakens but a system of superlong wavelengths of planetary dimensions emerges, such as the Qinghai-Xizhang mid-oceanic trough. The main high pressure body of the Qinghai-Xizhang high pressure system is especially strong and has become the strong and stable activity center of the entire globe's atmospheric circulation.

In addition, the temperature and the moisture contents of the atmosphere of the entire troposphere above the plateau are rather high. For many years, the average sounding curve in July at Lhasa under 470 millibars shows a super-moist adiabatic temperature reduction rate while above (470 millibars) it shows moist adiathermancy.[6]

To sustain the equalibrium state of this kind of atmospheric circulation above the Qinghai-Xizhang Plateau in summer, there must be frequent creation of cyclonic vorticity at low altitudes, there must be a creation of anticyclonic vorticity at high altitudes, and at the same time, there must be frequent upward transportation of heat and moisture.

The average perpendicular motion above East Asia in summer shows that in the middle and upper layers of the troposphere, the Qinghai-Xizhang Plateau is basically an upward movement area but the greatest center of upward movement is slanted over the Bay of Bengal. This ascending air flow moves in a southerly direction following the circulation along the 90° E

longitudinal circles. The descending airflow falls on the southern hemisphere.[7] This is the circulation of seasonal winds of Asia.[8] It is different from the circulation along the Hadley longitudinal circle over the Pacific.

In the past, people often used the existence of the circulation along the Hadley longitudinal circle to explain the convergent airflow above the subtropical high pressure system. But the intensity of the Hadley circulation over the northern hemisphere from winter to summer gradually weakens month by month while the intensity of the subtropical high pressure over the Pacific is stronger in summer than in winter. Therefore, Hadley circulation alone cannot fully explain the sustaining of the subtropical high.[9]

The vertical latitudinal circulation along 35°N shows that the airflow from the Xizhang plateau can flow directly eastward at high altitudes to the subtropical high pressure zone over the eastern Pacific and then descend. In addition, the ascending airflow from the continent of the eastern part of the plateau can move eastward at low altitudes over a short distance to the subtropical high pressure zone over the eastern Pacific and then descend.[7] Comparison of these two east-west circulations with the medium distribution of cold and heat sources in July over the northern hemisphere[2] shows that these two east-west circulations are two direct circulations of different wavelengths. The first rises from the region of the source of heat of the Xizhang plateau and ascends at the region of cold source over the eastern Pacific. The second rises from the heated region on the eastern part of the continent and ascends at the center of the region of cold source in the western Pacific. This kind of massive direct circulation produces the kinetic energy needed by medium circulations.

The average ascension above the plateau is formed by movements of many medium and small systems. One kind of medium and small system is the extremely active convection in summer over the plateau. Statistical analysis of high resolution cloud maps of 1700 megacycles of August, 1975, shows the south central part of the plateau is a cloudy zone.[10] Another type of medium and small system may be local orographic circulations.

The rotary cup simulation experiments also indicate that under the effects of heating from the plateau, a cyclonic convergence zone is formed on the ground surface near the plateau. The flowing bodies of air convectively rise and form an anticyclonic divergence field of flow at the upper part. This is the Qinghai-Xizhang high pressure system, and surrounding the plateau are air masses that are ascending.[10, 11]

Therefore, it can be said that in summer the moistening and heating effects of the plateau brings about potential instability in the atmosphere above the plateau. Cyclonic circulation at low altitudes easily converge. Widespread convective movements easily occur. The latter can transport

the thermal sensitivity and moisture of the layer near the ground upward and release potential heat and thus sustain large-scale circulation, and provide for the creation of low altitude cyclonic vorticity and high altitude anticyclonic vorticity. This is a kind of nonlinear mutual action between circulations of different scales.[6]

III. Establishing the Atmospheric Circulation in Summer Over East Asia--Seasonal Changes

The evolution of planetary scale circulation from winter to summer over East Asia is one of the processes having the most characteristic changes in global atmospheric circulation. In June, the Asian atmospheric circulation undergoes a violent seasonal change. Its major characteristics are:

1. The sudden northward shift of the planetary wind belt especially over the Qinghai-Xizhang Plateau region in East Asia, the sudden northward leap of the subtropical belt of westerlies and the westerly jet stream, and the disappearance of the westerly jet stream above South Asia establish the tropical easterly jet streams above the low latitudes south of the plateau.

2. The planetary circulation over the middle and high latitudes of the northern hemisphere undergoes a tremendous long-wave adjustment. The three to four long-wave troughs of spring become four to five long-wave troughs and the ridge phase undergoes a relatively big change. The large trough over the East Asian coast shifts inland over the continent.

3. In the tropopause, the high pressure center at 200 to 100 millibars suddenly leaps from the south to the north and stabilizes above the plateau.

4. At low altitudes in the troposphere, the Indian southwesterlies suddenly emerge and summer winds are active over regions in southern China. The position of the shear line above the plateau is stable. Low eddies develop frequently. The rainy season in most regions of the plateau begins. The polar front moves from southern China to the Changjiang valley, establishing the plum rains in the Changjiang-Huai River regions in our nation.

The characteristics of seasonal changes of the above circulations are very obvious and they affect our nation's synoptic climate greatly. But analysis of data of many years shows that the emergence of these characteristics is multifarious. Typical and simultaneous occurrences are uncommon and there is no definite order. Changes due to many phenomena make up an irregular yearly background of change. Therefore in recent years many more detailed studies have been made and some new facts worth attention have been discovered.

Analysis of data between 1961 and 1973 shows sudden changes occur in the subtropical westerly circulation over South Asia from spring to summer,

and such sudden changes occur the earliest in the lower layers of the troposphere, generally in March and April, and they occur the latest in the middle layers of the troposphere. At 500 millibars, they occur in July, and the closer to the plateau, the more sudden changes occur and they occur earlier.[12]

The date of disappearance of the subtropical westerly jet stream over East Asia south of the plateau can vary a lot according to different individual standards used. Some set the day early. If measured according to the evolution of the westerlies at high altitudes above Tengchong xian, the average date is on May 15. The southern boundary of the jet streams has retreated northward to the southern edge of the plateau.[13] Some set it late. If the high altitude westerlies over the several meteorological stations in South Asia are analyzed, the 300-millibar jet streams disappear from the south of the plateau on the average on June 14.[12] According to the average daily change in depth of the 500-300 millibars over Lhasa over many years, the depth suddenly increases before June 10. From this it can be estimated that the average time for the retreat of the jet stream northward should be before June 10, and by the time of the plum rains (average date is on June 18), temperature changes above the plateau are relatively small.

Plum rains over the middle and lower reaches of the Changjiang are an important synoptic phenomenon in the establishment of summer circulation. In recent years, people have discovered that before the plum rain comes, the subtropical high altitude westerly jet stream axis over East Asia has already retreated to the north of the Qinghai-Xizhang Plateau. After arrival of the plum rain season, jet streams are seldom seen to suddenly shift northward. In addition, jet streams that are active north of 40° to 45°N after the plum rain season can still return to the sky over Japan. These results are different from conclusions drawn from the lesser amount of data of the 1950's.[13]

Above 150 to 100 millibars over the region between 10° and 15°N over the southern part of the Qinghai-Xizhang Plateau are strong tropical easterly jet streams. Their center is relatively stable but the changes in the border regions of the jet stream zone are more obvious than changes at the center of the jet streams. High altitude winds at 18,000 meters over Nanning on the northern edge of the easterly jet stream change from westerlies to easterlies, and after about a month, the middle and lower reaches of the Changjiang enter the plum rain season. In mid-summer when rain over our nation's eastern regions is plentiful, the easterly jet stream intensifies. Otherwise it weakens.[14] But the time and scale of the seasonal shift of the belt of the easterlies is also definitely related to summer drought in Sichuan Province.[15]

The physical mechanism of this characteristic change in atmospheric circulation from winter to summer over East Asia is not clear, but this change

occurs over the Asian continent and it seems to occur first over the plateau region. This forces one to consider the thermal effect of the continent and the plateau. Annual changes of the heat and cold sources of the northern hemisphere show that in May and June, visible heating occurs over the East Asian continent in the northern hemisphere but such occurrence is not seen over the two oceans.[2] Because changes in radiation are relatively even, changes due to uneven heating are mainly dictated by the thermal sensitivity of the sea and land. The specific heat of the continent is smaller than that of the ocean, therefore the gain and loss of heat by the continent necessarily occur before the ocean. The release of potential heat caused by the raising effect of the kinetic forces of the large plateau topography will intensify this function of the plateau.

In the rotary cup simulation experiments, heating by the plateau brings about such interesting phenomena as a retreat northward by the westerlies belt, establishment of the easterlies belt and formation of the Qinghai-Xizhang high pressure system.

In the distribution of the anomalies of temperature and pressure of each layer along the 30°N latitudinal circle in July over the northern hemisphere, the greatest anomaly of positive temperature is exactly above the Qinghai-Xizhang and Iranian plateaus, not at the bottom part of the troposphere but in the tropopause. Heating and the potential heat in the tropopause above the eastern part of our nation and above the eastern part of the plateau may be the major aspects. It can be imagined that the heating effect by the plateau and by the Afro-Asian continent has weakened the longitudinal temperature gradient on the southside of the plateau and strengthened the gradient on the north side. As heat accumulates to a certain degree, it brings about violent changes in the westerly circulation of the subtropical zone. The strong thermal sensitivity caused by the raised surface of the plateau and the potential heat will cause a thermal low pressure to emerge in the layer near the ground of the plateau, and a warm high pressure to emerge in the tropopause. When the Qinghai-Xizhang high pressure system controls the entire tropopause, the south Asian westerlies undergo a sudden change.[12] This process is yet to be confirmed numerically.

We must point out that the yearly variations of seasonal change of the atmospheric circulation in East Asia from winter to summer is very great. The heating effect may only have provided the background physical causes. But the sudden change may be dictated to a greater extent by the nonlinear movement of atmospheric circulation itself (of course this also includes the mutual effects of heating and kinetic force). Northward retreat of the westerly belt is frequently realized through the adjustment of the ridge, therefore each year's seasonal change can be very different.

IV. Changes in Circulation During the Peak Period of Summer Circulation

After summer circulation has been established and although the large circulations of planetary scale such as the Qinghai-Xizhang high-pressure system and the tropical monsoons are all strong but relatively stable activity centers over the northern hemisphere, they still show visible changes after they are established and they control the evolution of the macroclimate over East Asia.

1. The East-West Oscillation of the Qinghai-Xizhang High Pressure System

The summer Qinghai-Xizhang high-pressure system seems to oscillate back and forth from its medium position. Every oscillation of the high-pressure system about its position brings about an adjustment of the type of high altitude flow over South Asia. At the same time, the subtropical high-pressure system over the western Pacific also undergoes a corresponding advance or retreat.[16]

When the Qinghai-Xizhang high pressure shifts from its medium position and away from the sky above the plateau and reaches the eastern part of the continent, it is called the eastward type. When the high-pressure center reappears west of the 100°E above the plateau, it is called the westward type. There is also a transitional type between the two types above called the zonal type. The westward type constitutes 70 percent of the total number of days of all types of circulation. Therefore, the Qinghai-Xizhang Plateau which serves as the heat source relates to the formation of the Qinghai-Xizhang high-pressure system in an important way.[17]

The three types of circulation mentioned above mutually interchange and their course of change is of medium duration of over 10 days. As shown by spectral analysis the activity of the high-pressure circulation at 100 millibars has mainly a long cycle of from 10 to 16 days. There are also activity cycles of 1 week's duration.[18]

East-west oscillation of the Qinghai-Xizhang high-pressure system in the 40° to 50°N latitudinal circle of the westerly belt manifests itself mainly as adjustment of the long-wave system of the subtropical zone above the plateau. The trough of westerlies that causes the strong and stable westward type Qinghai Xizhang high-pressure system to move out of the plateau is mainly the trough east of 70°E that suddenly emerges toward the plateau. The already existing eastward moving trough west of the 70°E cannot force the Qinghai-Xizhang high-pressure system to move eastward. This was also proven in the rotary cup simulation experiment.[19]

But the transformation of the types of circulation of the Qinghai-Xizhang high-pressure system is complex. Changes in circulation are frequently hemispheric. The relationship between the major systems of circulation is also not simple. For example, the subtropical high-pressure system over the western Pacific and the Qinghai-Xizhang high-pressure system can

move in the same or opposite directions. They adjust themselves at certain positions or separate within a definite wavelength. The mid-Pacific trough is also a key system. When the mid-Pacific trough stabilizes at its medium position or reestablishes itself, the subtropical high-pressure system over the western Pacific also stabilizes and intensifies.[20] In addition, when the subtropical high-pressure system over the western Pacific combines with the northward moving equatorial buffer belt of the South Sea, such a combination is definitely related to the transformation of the Qinghai-Xizhang high-pressure system from an eastward type to a westward type. Studies of spectral analysis also indicate Hankou is frequently at the edge of the Qinghai-Xizhang high-pressure system and the subtropical high-pressure system of the western Pacific, while the mutual relationship between 100 millibars above Lhasa and 500 millibars above Shanghai proves that the Qinghai-Xizhang high-pressure system does not always control the activity of the subtropical high-pressure system of the western Pacific. Sometimes changes in the latter precede activities of the continental high-pressure system.[18]

At present, three postulations exist in our nation concerning the mechanism of oscillation of the Qinghai-Xizhang high-pressure system:

(1) The effects of heating is emphasized. It is believed that the transformation of the Qinghai-Xizhang high pressure from an eastward type to a westward type is mainly due to the effects of thermal sensitivity of the plateau west of 100°E. A new high-pressure center forms to the west of the ascending divergent air column while the transformation from the westward type to the eastward type is mainly due to the release of potential heat from the regions east of 100°E.[22]

(2) The atmospheric movement is emphasized. It is believed that the east-west oscillation of the Qinghai-Xizhang high-pressure system is related to the adjustment of the entire long-wave system and it cannot be due only to changes in regional geothermal conditions.[21]

(3) Two processes are proposed: self-oscillation and forced oscillation. The first is due to adjustment of the subtropical long-wave system caused by heating from the plateau. The second is due to adjustment of the wave system caused by the unstable development of subtropical long waves.[23]

2. Circulation of Seasonal Winds (Monsoon)

After the summer circulation has been established, the entire region of South Asia, Southeast Asia, the Qinghai-Xizhang Plateau and our nation's southern part becomes the peak summer wind zone. Monsoon is a concept established on factual observations of low altitude wind systems. The classical definition of monsoon is the peak airflow of winter and summer surface winds of opposite directions. The development of high altitude synoptic meteorology has enriched and complicated the meaning.

The strong southwesterly monsoon that controls the Indochina Peninsula and India is the famous tropical monsoon. Its climatological and synoptic concepts are relatively clear. Activity and intermittent calm of the southwesterly monsoon are the indicators for forecasting rain in this region. To our nation, the important question is the relationship among the activity and intermittent calm of the southwesterly monsoon and our nation's weather.

The monsoon phenomenon is prominant in the Yunnan-Guizhou Plateau of our nation. The southwesterly monsoon begins to blow in Guizhou on the average between the middle and the last 10 days of June. It is related to the occurrence and development of the monsoon low pressure north of the Bay of Bengal. Also, the date on which the plum rains begin in the middle and lower reaches of the Changjiang and the date of the peak period of the southwesterly monsoon over Guizhou are very close and their relationship is close.[24] But the beginning date of the rainy season in Yunnan is more complicated. The rainy season in the Kunming region begins in the middle 10 days of May, close to the average beginning date of the tropical southwesterly monsoon of East Asia but in some places the dates are very inconsistent. The rainy season begins the earliest in northwest Yunnan, not in southwest Yunnan. It is worth noting that the course of rainfall during the rainy season in Yunnan is mostly produced by a combination of the southerly winds and southward movement of cold air.[25] This is different from the simple rainfall due to the tropical monsoon.

We believe our nation's monsoons are not sufficiently clearly defined as a synoptic concept. Should the subtropical monsoon be differentiated from the tropical monsoon? Two months before the sudden emergence of the tropical southwesterly monsoon in India, the rainy season in the Yunnan-Guizhou Plateau has already begun. The southwesterly wind at this time is a subhigh westerly airflow. The rainy weather is related to the activity of the south branch westerly wind trough. If the southwesterly airflow of the Yunnan-Guizhou Plateau is labeled as a monsoon, then it should be a subtropical monsoon. After the tropical monsoon is established in India, it can be estimated that at some time, the ITCZ (Indian tropical convergence zone) shifts to northern India, and the easterly wind on the north side of the ITCZ separates the subtropical monsoon and the tropical southwesterly monsoon of our nation's regions south of the Changjiang. When the Indian monsoon low pressure shifts to the northwest corner of India and the ITCZ breaks off, the tropical monsoon can affect the subtropical, and a mutual action between different latitudes visibly occurs.

3. Low Altitude Circulation

The atmospheric circulation in summer over East Asia is greatly affected by tropical circulation. Although the massive Qinghai-Xizhang Plateau can serve to shield tropical airflow, the northernmost ITCZ of the northern hemisphere is also near the plateau. This is a very interesting phenomenon.

An absolute majority of typhoons of the western Pacific occurs in the ITCZ. The strength or weakness of the ITCZ determines the number of typhoons that occur. The characteristics and structure of the circulation of the ITCZ are worthy of attention. The characteristics of the atmospheric circulation at low latitudes when the ITCZ is strong and when it is weak are very different. The positioning and the intensity of the several activity centers are visibly different. On the one hand, the differences in the characteristics of circulations at low latitudes exert important influences upon the tropical synoptic system and the number of typhoons.[26] On the other hand, circulation at low latitudes is closely related to the type of subtropical flow. When the ITCZ is active, activity of the southwesterly wind over the western Pacific is intense, the southwesterly monsoon over India weakens or ceases, and the anticyclonic eastward extensions above the Qinghai-Xizhang Plateau are also intense. When the ITCZ is weak, central India becomes a monsoon trough. Monsoons are active, and the anticyclonic circulation above the Qinghai-Xizhang Plateau flows westward.[27] Study of the 3 dimensional structure of the ITCZ shows that an anticyclone at 200 millibars superimposes itself near and on the north side of the ITCZ. It is helpful in sustaining and intensifying the ITCZ.[28]

Airflow over the southern hemisphere also greatly affects atmospheric circulation over East Asia. As early as the 1960's, our nation's meteorological workers discovered that near the Rabaul weather station (94085) in the equatorial zone is the place where the airflow of the southern hemisphere concentrates and crosses the Equator. In recent years people have noticed the existence of several passages of airflow that cross the Equator. One major passageway is the strong and narrow low latitude jet stream at Somalia on the east coast of Africa. This jet stream's annual variations are consistent with the variations of the airflow of southern India, the southern part of the Bay of Bengal to the Indochina Peninsula and the southern part of the South Sea of our nation.[29]

There are two possible passageways that cross the Equator in the Southeast Asian area. One is near 105°E and the other is near 150°E.[30] The latter is on the east coast of New Guinea. It is not like the jet stream of Somalia where strong winds of high wind speeds are sustained frequently. Winds occur intermittently. Their formation may be similarly due to the effect of the African continent upon the jet streams of Somalia, and is greatly affected by the effect of topographic blocking that occurs at New Guinea.[29]

V. Synoptic Scale System Under the Control of Summer Circulation

Under the control of the circulation of planetary scale in summer are many intermediate scale and large scale synoptic systems in the East Asian region. Their activities create summer rains. Therefore in synoptic analysis and forecasting they are very important.

In recent years, it was discovered that the Qinghai-Xizhang Plateau is an origin of low eddies. Statistics of existing satellite data and weather stations show there are generally five origins: Qingtang, Nagqu, Qaidam, Songpan, and Sichuan. The major one may be the Nagqu low eddy. It is frequently connected to the plateau shearline. Medium horizontal circulation indicates that between the thermal low pressure of the plateau and the low-pressure trough of the Indian monsoon at 3,000 meters there is a rather complete anticyclonic circulation.[31] On the large scale monsoon's vertical circle of circulation on the north and south sides of the plateau there are smaller longitudinal circles of circulation. The convergence zone of the airflow north and south of the north side of the plateau is the medium latitude of the summer shear line.[7]

The plateau shear line is warm and does not have an obvious frontal zone. The low eddy above the plateau may be thermal in nature. Although the westerly wind trough does contribute importantly to the formation of these systems, only 10 percent of the plateau's synoptic systems can exert direct influence upon the plateau. Therefore in recent years more attention has been paid to the thermal causes of the formation of low eddies. These include thermal sensitivity of the ground surface and the effects of convective condensation and the presence of potential heat. Before the low eddy of the plateau emerges at 500 millibars, convection cloud masses and rain already exist, and at the same time the thermal sensitivity of the ground surface reaches a maximum. Therefore it is believed that the mechanism for the occurrence of low eddies above the plateau probably is the following: The thermal low pressure of the plateau develops under the increasing thermal sensitivity of the western part of the plateau, thus strengthening the southwesterly warm and damp airflow of the central part of the plateau, while the release of potential heat and convective condensation cause the low pressure to develop further. Since in summer the plateau relative to the surrounding atmosphere is a high temperature and highly damp region, this mechanism indicates that the development of low eddies over the plateau are similar to the development of tropical cyclones.[32] According to analysis of data of satellite cloud pictures, the major source of energy for the development of the southwest eddy is also the release of potential heat, condensation and unstable convection.[33]

The southwest eddy of the east side of the plateau and the development of the Songpan eddy which originates on the north side of the plateau are frequently related to the activities of the westerly belt system. At this time, the effects of transformation of thermal and kinetic forces caused by the entry of cold air into the newly formed warm eddy are very important. Increased warming of the plateau forms an over-heated wind formation center, and the eastward advection of the cold trough affects and determines whether the over-heated wind formation center develops.[34]

Numerical simulation of the disturbance of the latitudinal circle of circulation caused by the plateau shows the downstream trough of the plateau is a lot further to the east than the Rocky Mountains. Therefore

as regards the westerly belt, although our nation is situated on the leeward slope, formation of cyclones occurs visibly mostly only in the eastern provinces,[35] for example, our nation's northeastern low-pressure system, cyclones of the Yellow River and cyclones of the Changjiang and the Huai River.

In recent years, further understanding has been gained in the occurrence and development of cyclones of the Changjiang and the Huai River. Diagnostic analysis proves that the release of potential heat and condensation exert a major effect upon the occurrence and the development of cyclones.[36,37] One interesting phenomenon is that frequently rain occurs above the stationary front and then a cyclone forms. The mechanism of this kind of process obtained by numerical simulation is described as follows: The low-altitude shear flow field above the stationary front possesses a rather weak low altitude convergence. High altitude divergence forms a rather weak rising movement so that air masses with nearly saturated vapors rise up causing the weaker to drop as rain. The condensation of potential heat hinders changes in the temperature and pressure field and because of kinetic limitations, it strengthens the low altitude convergence and high altitude divergence of the flow field, and at the same time, it strengthens convergence of low-altitude water vapors. Between such large-scale condensation and large-scale circulation, a strong positive feedback is formed at parts of certain regions. This kind of "condensation feedback instability" mechanism causes the atmospheric pressure at the ground surface to drop, more rain and formation of low altitude jet stream wind speeds.[38]

It can be seen from the above that atmospheric circulation and synoptic processes in summer over East Asia are the results of uneven heating due to a complex distribution of land and sea, and the mutual action of atmospheric movements at different latitudes and of different scale under kinetic thermal effects of the large topography of the Qinghai-Xizhang Plateau. In the past we have obtained a lot of results but many questions still remain. We hope that within the next 10 years, greater progress will be made.

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STATUS OF RESEARCH ON RAINSTORMS, SEVERE CONVECTIVE WEATHER

Beijing DAQI KEXUE in Chinese Vol 3, No 3, Sep 79 pp 227-237

[Article by Tao Shiyan [7118 6108 6056], Ding Yihui [0002 0001 0565] and Zhou Xiaoping [0719 2556 1627], Institute of Atmospheric Physics, Chinese Academy of Sciences; manuscript received 24 April 1979: "The Present Status of Research on Rainstorms and Severe Convective Weather"]

[Text] Ours is a country of numerous rainstorms, and these frequently cause serious flooding. Since the founding of the state, the 1954 Yangtze flood, the 1958 Yellow River Flood, the 1963 Hai [3189] River Flood and the 1975 Huai and Yellow River floods all were produced by prolonged heavy rainstorms. Our country is located in East Asia, and every summer it is affected by the summer monsoon. A vigorous monsoon can reach north China, the northwest, or even the northeast. Against the background of this circulation, the added effect of this country's complex physiography results in the regular occurrence of strong rainstorms. There is a clear difference here from the situation in America, where local strong convective weather (tornadoes, thunderstorms and the like) is predominant. After the exceptionally large rainstorms in Henan in the first 10 days of August 1975, the problem of rainstorms further attracted the serious attention of various meteorological departments. In 1977, this country set up the South China Pre-Flooding Period Rainstorm Experimental Observation Network and pursued a multifaceted rainstorm research cooperative program; subsequent work has yielded many important results, producing a certain improvement in the level of rainstorm research and forecasting in this country.

1. The Large-Scale Circulation Background of Rainstorm Development

Many major rainstorms appear during apparent adjustments of large-scale circulation; for example, rainstorm No 75.8 [August 1975] developed when the East Asian zonal circulation was developing into meridional circulation.[1] Major thunderstorm No 58.7 on the Yellow River also developed when the zonal long-wave system in the eastern hemisphere was undergoing a phase reversal adjustment.[2] In addition, prior to the occurrence of rainstorm No 58.7 (11-15 July), 2 long-wave troughs had been present at 40°E and 110°E, with a long-wave ridge between them at 80-90°E. Fifteen days later,

rapid phase-reversal changes occurred in the long-wave system, and the 80-90°E area changed into a stable long-wave trough, while the areas at 40° and 110°E changed to long-wave ridges. This type of adjustment caused a long-wave trough and upper-air cold cyclone system to stabilize in the western part of our country, causing prolonged heavy rainstorms to occur in the Yellow River region. Many investigations of long-range circulation patterns of rainstorms have already been made. For example, on the basis of analysis of many large and exceptionally large rainstorms in this country, we generalized 11 rainstorm circulation patterns,[3] of which the circulation patterns which can produce exceptionally large or persistent rainstorms are particularly important. The main characteristic of the circulation patterns associated with persistent exceptionally large and heavy rainstorms under meridional circulation conditions is that the Japan Sea high and the Qinghai high stand in stable opposition to each other, and cold air continuously flows along the Lake Baykal high into this high-altitude trough or shear line between the two high-pressure areas. The main characteristic of circulation patterns associated with thunderstorms under zonal circulation conditions is that cold air which separates from the extensive Siberian low-pressure trough and moves southeast continuously comingles with warm moist air currents from the west side of the subtropical high, forming continuous rainstorms.

In recent years, three different years in the investigation of large-scale rainstorm circulation patterns have been stressed. The first is the effect of interaction of middle and low latitude circulation systems, particularly low-altitude ones. Research makes it clear that the effect of a tropical circulation system can be discovered in every heavy rain. For example, in the Nos 75.8 and 63.8 heavy rain periods, the tropical convergence zone had moved noticeably farther north. Similar phenomena occurred in the other summer heavy rainstorm periods.

Northward movement of the tropical convergence zone strengthened southwest air currents and southeast air currents, providing major sources of water vapor, while at the same several low-pressure systems in the tropical convergence zone moved directly north to produce the rainstorms. Recent analyses have also pointed out[4] that owing to the fact that the subtropical convergence zone generally has more than one cyclone, if when a typhoon reaches land there is still a low present or developing to form a vortex group, the vortex group and the northerly subtropical high form a strong eastward air current between them which reaches from the sea inland and provides a main avenue for water vapor to produce rainstorms. Secondly, stress has been laid on the blocking action of the subtropical high and the Japan high.[5] The stability and persistence of the Japan high are generally an important factor in the formation of northern rainstorms or extraordinarily heavy rainstorms. The stable persistence or westward extension of these systems in the areas downwind can cause rainstorm systems to slow down, stagnate or rotate, which is favorable to the formation of persistent rainstorms. Third, stress has been laid on the effect of weak cold air. In many rainstorms, it has been discovered that

low-level cold air has influenced the heavy rain area from the northwest or northeast, so that a shallow occluded front can generally be distinguished in the vicinity of the heavy rains.

2. Weather Systems Which Form Rainstorms and Their Vertical Circulation

The weather systems producing rainstorms in our country are quite numerous, including typhoons, cold fronts, low-pressure vortices, high-altitude troughs, shear lines, moist tongues on the north sides of the subtropical high and the like; of these, the influence of typhoon rains is the greatest. Many investigations make it clear that when the typhoon and middle-latitude weather systems combine, the resultant rainstorms are particularly intense. For example, in the typhoon rains that fell in Xinliao [2450 1402], Taiwan Province, on 17-19 October 1967, 1,672 millimeters of rain fell in 24 hours and a total of 2,769 mm in 3 days; this was because of the combined effect of a cold front and the typhoon,[6] and was the most intense rain that has occurred in our country. In addition to the systems mentioned above, investigations on preflood season rainstorms in south China have revealed that rainstorms can also be induced by some low-layer (under 850 mbar) submeteorological systems (primarily taking the form of low-layer shear lines).[7,8]

The three-dimensional airflow structure within the rainstorm system is very important for understanding the formation of rainstorms. Browning et al have done considerable research on this subject. On the basis of recent research on the three-dimensional airflow structure of some heavy rain systems in this country, we can generalize five flow structures.

The first is the typhoon rain circulation structure (Fig. 1a). The area most favorable to development of rainstorms is on the eastern or northeastern side of the typhoon circulation. Here there is an area of strong rising air produced by a northward jetstream (or southward low-layer jetstream). The lower-atmosphere jetstream also transports large quantities of water vapor. In addition, the superposition of the lower-atmosphere eastward jetstream and the middle-level southward (or westward) airflow forms the conditions for instability release and reconstitution. The vertical wind shear is also quite evident. In this area there is a zone in which the low pressure northward cold air and the eastward (or southward) airflow form a medium-size shear line, which is an initiating mechanism for convective development. In the upper levels there is a clearly-marked anticyclonic divergent circulation. All of these conditions are favorable to the development of cumulonimbus and rainstorms. If the large-scale situation is stable, persistent rainstorms can develop.[9] If the high-level divergent circulation is not present or changes to a convergent circulation, then the heavy rains are generally checked, and only a brief period of intense rain occurs; this situation occurred during the typhoon rains of 25 July 1978 and 27 July 1972 in Peking.

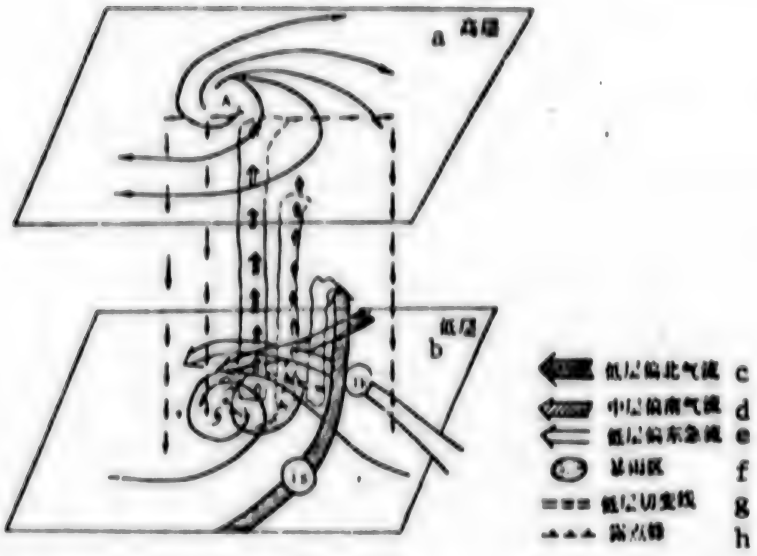
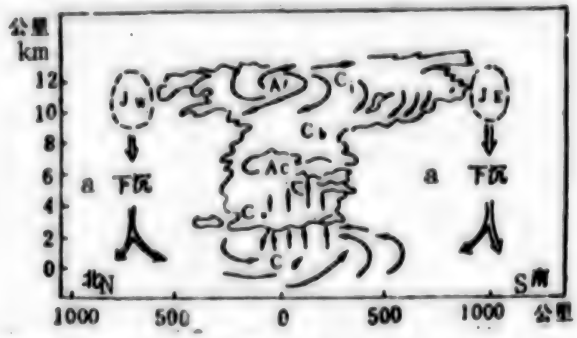


Fig. 1a. Circulation structure of persistent typhoon rains

Key:

a. High-altitude layer
b. Low-altitude layer
c. Lower-layer northward airflow
d. Mid-layer southward airflow
e. Lower-layer eastward jetstream
f. Rainstorm areas
g. Lower-layer shear line
h. Dewpoint front

The basic characteristic of the second circulation structure is that a low-pressure vortex system is at the lower level, while above 200 mbar there is a clearly marked anticyclonic circulation; to the south and north there are generally an eastward or southward airflow, which intensifies divergent flow at that level [Fib. 1b). This lower-air convergence and higher-air divergence is favorable to persistent occurrence of convective flow in the rain region. Such circulation patterns generally occur in the rainstorms of the preflood season in south China. Examples are the rainstorms in Hong Kong on 12 June 1966 and the middle third of June 1972,[10] and the rainstorms in Taishan, Guangdong Province on 28 May 1973 (where precipitation reached 850 mm in a 24-hour period).



Fib. 1b. A circulation structure for a south China rainstorm

Key: a. Subsiding

The third type is the vertical circulation loop[11] associated with northern low-pressure trough cold front storms (Fig. 1c). There are two clearly evident circulation loops in the vertical cross-section of the cold front, surrounding the rainstorm area. Strong rainstorms occur in the ascending branch of southward-facing or eastward-facing vertical circulation loops. If a low-altitude jetstream is present, the ascending airflow is positioned to the right of or in front of the jetstream axis. Another clearly evident characteristic is that generally on its north or west side cold air is descending from the middle and upper layers; this flows down to the forward part of the front and converges with the airflow from the south or east, further intensifying airflow in the ascending branch. Accordingly, intense rainstorms or strong convective activity associated with this kind of cold front primarily appears in the strong ascending airflow ahead of the front. This generally occurs in fast-moving summer cold fronts in north China. The main characteristics of the vertical circulation structure of upper-air cold front rainstorms are shown in Fig. 1c, but the intense vertically-rising airflow occurs primarily in the middle or upper troposphere. The exceptionally large rainstorm (over 1,050 mm precipitation in 8 hours) which occurred on the afternoon of 1 August 1977 in the area between northern Shaanxi and Inner Mongolia was of this type.[12]

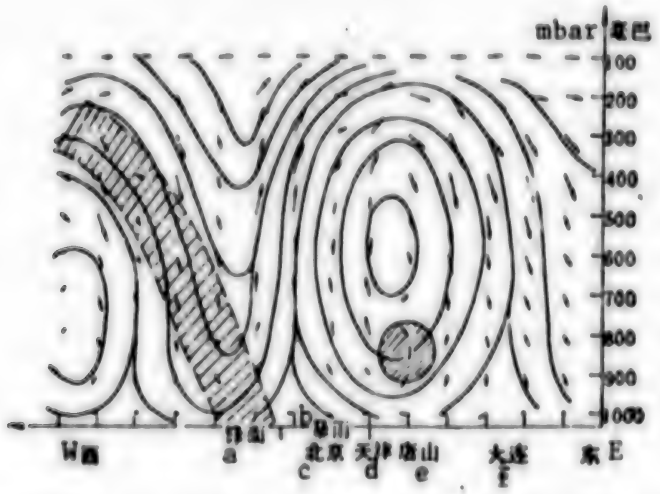


Fig. 1c. Circulation structure of a cold-front rainstorm

Key:

a. Frontal surface
b. Rainstorm
c. Peking
d. Tianjin
e. Tangshan
f. Dalian

The fourth structural type is the vertical flow structure typical of the Yantze-Huai Plum Rains period and the south China quasistationary rainstorms (Fig. 1d). Because the cold air is modified or becomes weakened, the altitude of the frontal surface is low and the slope is small, the

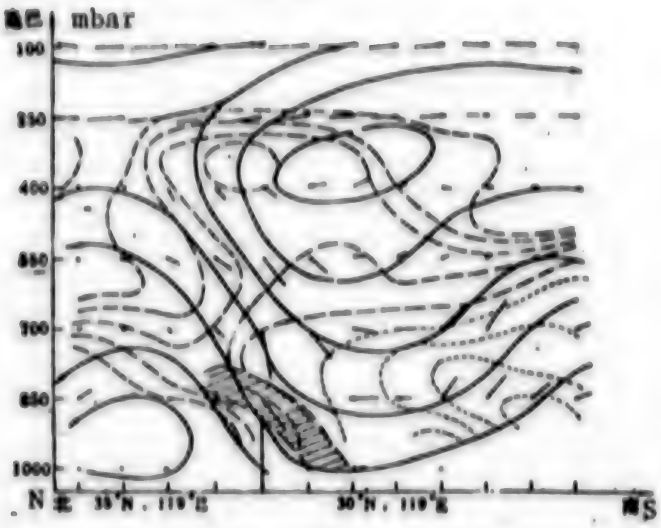


Fig. 1d. Circulation structure of a quasistationary front

warm air is active, generally taking the form of warm moist air from the south rising spontaneously along the frontal surface, with rainstorms occurring in the unstable airflow along this upslope (between the surface cold front and the 700 mbar shear line). If the cold air is relatively strong, the slanting upward airflow along the frontal surface can turn in the vertical direction above the front.[13,14] Vertical circulation in rainstorms of the south China quasistationary front and in the Yantze-Huai Plum Rains structure are very similar, having primarily airflow which is potentially unstable flowing on a slant along the middle or low-layer front.

The fifth type is vertical airflow associated with a warm shear line.[15,16] Because wind convergence is most intense in the vicinity of the shear line, strong rising airflows are present. The shear lines are generally almost vertical, and the rainstorms and strong convection appear near them (Fig. 1e). If a low-level jetstream is present in the southward warm, moist airflow on the south of the shear line, because the wind velocity convergence within it is much more intense than that in the vicinity of the shear line, rainstorms and strong convection can appear south of the surface shear line.

3. Physical Conditions for the Appearance of Rainstorms and Strong Convection

Rainstorms and strong convective weather are closely connected with environmental conditions (including thermodynamic and dynamic ones). Large-scale environmental conditions not only control the nature and the development of rainstorms and strong convective weather but also can affect the internal structure, strength, movement and degree of organization of convective systems. In the large-scale environment, organized convective systems are

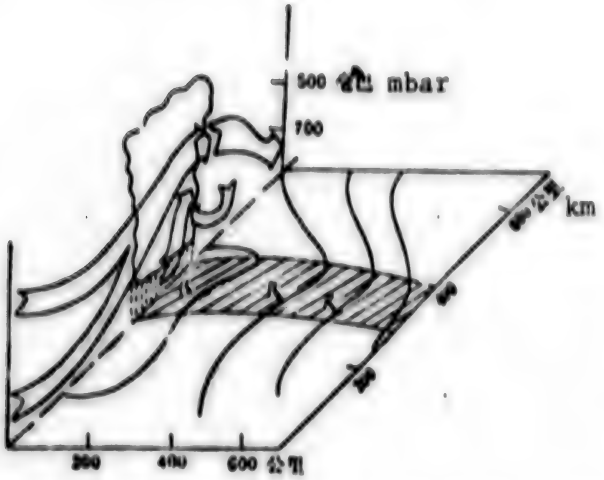


Fig. 1e. Circulation structure of a warm shear line.

not randomly produced or distributed, but appear in definite areas and at definite times, a fact which is currently used as a basis for making mid-range weather forecasts. The physical conditions for rainstorms and strong convective weather used to be described in many categories, but in the main they must satisfy the following conditions: 1. a positionally unstable stratification, in addition to which thunderstorm systems also require the presence of an inversion layer; 2. a moist tongue or water vapor convergence in the lower level; 3. a mechanism for release of the potential instability (such as lower-air convergence, gravity waves, density waves, topography and the like); 4. low-level or high-level jetstreams; 5. strong thunderstorms require strong vertical wind shear; 6. for strong convective weather, cold dry air in the middle level. Although there is currently a better understanding of the connection between the above conditions and rainstorms or convective weather, it is still not entirely clear just what the physical connection between these conditions and the development of medium-scale conditions is, and the cause-and-effect relationship between the two has not been entirely clarified. This is due in large measure to the limited nature of observational data. We should point out that rainstorms and strong convective systems on the one hand and large-scale environmental conditions on the other are in different stages of development, and their degrees of interdependence and interaction are different. As they arise, and in their initial stages of development, they are primarily governed by large-scale environmental conditions, but after rainstorms and strong convective weather have undergone intense development, the large-scale environmental conditions not only lose their ability to control them but may, in fact, themselves be affected by convective storms.

In recent years, the investigation of the various physical conditions has concentrated on the three problems described below. One is the effect of

lower-level jetstreams; many statistics make it clear that in both the north and the south,[17, 18] rainstorms are closely connected with lower-air jetstreams, with a correlation rate of up to 80 percent. Generally, rainstorms are frequent to the right of or in front of the jetstream axis or in front of the centers of greatest wind velocity. On the average, 2.5 days elapses between the establishment of a lower-air jetstream and the appearance of the rainstorms.[19] Accordingly, analysis of low-level jetstreams has a certain significance for forecasting. The altitude of the jetstream axis is generally between 1.5 and 3 kilometers, and sometimes another jetstream center can develop in the boundary layer (950-900 mbar). Many analyses make it clear that disturbances propagating along the jetstream axis are more important than the jetstream itself as far as rainstorms are concerned, and three salient facts have been discovered:
1. when a medium-sized high windspeed center is present along the low-level jetstream, it propagates along the jetstream axis, and the corresponding rainstorm area to its left and front also shifts down the jetstream. Sometimes during a large rainstorm process, several medium-size high velocity centers may be found propagating. Each of these has a vertical circulation loop accompanying it, rising ahead of the high wind speed center and descending behind it; the rainstorm is a strong upward flow occurring in front of a jetstream high windspeed center. Analysis has also revealed that as the high windspeed centers propagate, the corresponding heat, humidity and potential instability maximum centers also propagate down the jetstream, so that lower-atmosphere jetstreams propagate momentum heat and water vapor along themselves in the form of medium-size pulses;
2. According to studies of some mountain observatory wind-velocity data, during the process of propagation of a medium-scale high wind velocity center, changes in wind velocity are highly nonuniform, having a shorter-period, high-amplitude (up to 10-12 m/sec) pulses.[20] When a high wind-velocity center in a jetstream passes, such wind velocity pulses can occur 5 or 6 times, and these are moreover quite closely connected with rainstorm intensity changes or pulsations. Fig. 2 illustrates the correspondence between rain fronts and changes in the windspeed at Tianshan [1131 1472] Mountain. Almost every rain front corresponds to an intense wind pulse. This perhaps indicates that windspeed pulses are closely connected with the development of medium-scale rain areas; 3. Low-level jetstreams are by no means supergeostrophic throughout; sometimes they are in geostrophic equilibrium. Only in high windspeed regions or when the windspeed is clearly intensified do supergeostrophic phenomena develop. In the establishment and breakdown of geostrophic equilibrium, wind field changes are ahead and wind pressure field changes follow; rainstorms appear in strongly nongeostrophic intervals. The abovementioned short-periodic windspeed pulses may reflect the effect of a series of gravity waves induced by nongeostrophic motion.

Currently there is no common viewpoint regarding the causes of low-altitude jetstreams. In the past, inertial oscillations of the boundary layer were used to explain the development of low-level jetstreams at night, and later some advocated the accelerating effect of blockage by mountain ranges on

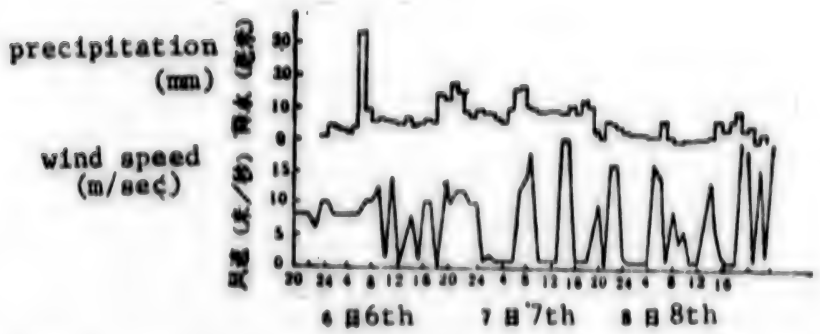


Fig. 2. Windspeed changes (peaked line) on 6-8 June 1978 at Jiuxianshan [0046 0103 1472], Fujian (altitude 1,644 meters), and associated time distribution of maximum precipitation (squared line) within 150 km downwind

jetstreams. In recent years, downward transfer of horizontal momentum has been used to explain the formation of lower-atmosphere middle-size jetstreams. Others use geostrophic winds produced in the development of pressure systems (such as intensification of westside lows) to explain the formation of large-scale lower-atmosphere jetstreams. This problem merits further investigation.

The second problem is the effect of the boundary layer. Investigation of rainstorms in north and south China has revealed that during the storms, at 500 meters (roughly 950 mbar) the horizontal convergence reaches a maximum,[21, 22] and water vapor and temperature are also high, so that the contrast between cold air and warm air is also quite apparent (Fig. 3). When a rainstorm is weakening, the convergence maximum in the upper atmosphere disappears. As a result, momentum, water vapor and heat convergence in the upper atmosphere make a great contribution to rainstorms. Moreover, before rainstorms and intense weather develop, the accumulation of momentum, heat and water vapor occurs first in the boundary layer, while the boundary layer windspeed maxima are achieved earliest. Afterwards they are transferred upwards again. This result means that the boundary layer makes an important contribution to the establishment of potential instability strata, water vapor supply and induction of the rainstorm.

The third problem is to study the differences in the physical conditions for rainstorms and strong convective weather (such as hail, thunderstorms and tornadoes). According to recent studies, the two show a good many clear differences.[23] According to comparison of average stratification of thunderstorms and strong convective weather, during the latter there is an inversion or isothermal layer near the ground, whereas this is not present in windstorms. Above 750 mbar, the temperature of strong convective weather is clearly lower than that of rainstorms. At 400 mbar the difference is 8°C.

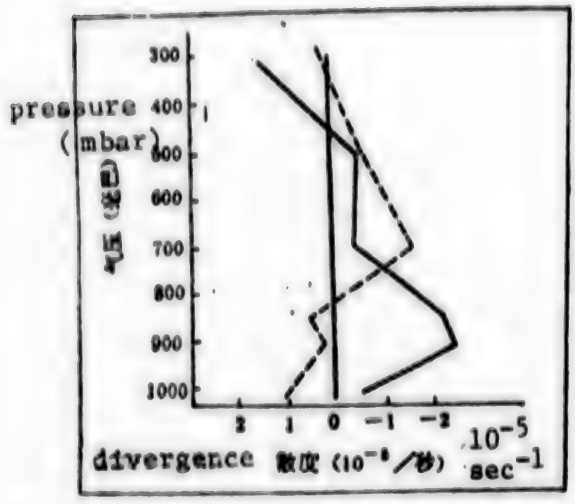


Fig.3. Vertical divergence contour (in 10^{-5} sec^{-1}) for Peking at times of intensifying (solid line) and weakening (broken line) rainstorms

Accordingly, below 7 km the rate of decrease for strong convective weather is 1-3°/km greater than for rainstorms. This results from air in the middle and upper layers. The latent instability energy layer for strong convective weather is thicker than that for rainstorms, but the free convection altitude is somewhat higher (Table 1). This means that strongly convective weather requires more intense initiating conditions before it can break out. But when it develops, the intensity of convective development is greater than that of rainstorms. The differences in physical quantities in the boundary layer are also very great; the humidity in an incipient rainstorm is much greater than that in incipient strong convective weather. The differences in maximum potential precipitation, overall water vapor convergence, vertical transfer of water vapor, which express water vapor content and water vapor sources, are also quite marked. The total water vapor convergence in a rainstorm may be three times that for convective weather. This means that in order to maintain a rainstorm, water vapor must converge on the rainstorm area at a rate two times greater than that for convective weather, and for strong convective activity the water vapor content must be even greater than that initially present in the air column itself.

Differences in vertical wind shear are also pronounced. Rainstorms develop under weak wind shear conditions, while strong convective weather develops in strong wind shear conditions. Fig. 4 compares average vertical shear for a rainstorm ahead of a trough and strong convective weather; the differences between the two are clear. The main factor producing large differences in vertical shear is differences in high-altitude windspeed. Strong convective systems are mostly located near the axes of upper-air jetstreams, while rainstorms are mostly located in a belt 200-500 km south of jetstream axes. Strong vertical shear is an important condition for the maintenance of strong convective windstorms.

Table 1. Comparison of Physical Conditions for Occurrence of Rainstorms and Strong Convective Weather

天气 a \ 物理量 b	凝结高度 (mb) c	自由对流高度 (mb) d	抬升指数 (℃) e	对流层顶高度 (mb) f	1—9公里平均递减率(℃/100米) g	10—12公里平均递减率 h	0℃层高度 (mb) i	K 指数 j	900mb 以下最高温度 k	900mb 以下最大比湿 l	975—275 mb 最大可降水 (mm) m
n 暴雨	935	820	3.5	119	0.63	0.67	600	35.1	27.3	17.5	4.8
o 强天气	835	670	5.2	227	0.72	0.40	630	34.8	24.5	13.5	3.1

天气 p \ 物理量 q	地面—300 mb 水汽水平辐合* r	通过边界层顶的水汽输送* s	纬向风垂直切变(10^{-3}秒$^{-1}$) t	θ_{se850}	θ_{se500}	$\Delta\theta_{se}$ (850—500)	T_{d850}'	T_{d500}	T_{850}	T_{500}
n 暴雨	1.9	2.0	1.0*	75.0	78.3	−2.9	−4.4	17.0	−2.2	19.4
o 强天气	0.85	0.55	3.5	56.4	63.4	−6.8	−17.3	12.1	−8.4	18.1

* 单位: 10^{-4} 克/厘米²秒. units: 10^{-4} g/cm^2-sec

Key:
a. Weather
b. Physical quantity
c. Condensation altitude
d. Free convection altitude
e. Rise index (°C)
f. Altitude of top of convection layer
g. Average lapse rate, 1-9 km (°C/100 m)
h. Average lapse rate, 10-12 km
i. Altitude of 0°C layer
j. K index
k. Maximum temperature below 900 mbar
l. Maximum relative humidity below 900 mbar
m. Maximum possible precipitation between 975 and 275 mbar
n. Rainstorm
o. Strong convective weather
p. Weather
q. Physical quantity
r. Horizontal water vapor convergence, surface-300 mbar
s. Water vapor transfer through boundary layer top
t. Zonal vertical wind shear (10^{-3} sec $^{-1}$)

The differences in certain physical quantities which express air mass characteristics are also quite evident. In comparing T_{d850}, T_{d500}, T_{850}, T_{500}, θ_{se850} and θ_{se500} we find that the difference in lower-air humidity is the main one, the temperature difference is not great, and the lower area of a rainstorm consists of high-temperature high-humidity air, while the humidity of the air in strong convection is much lower: it can be a modified polar continental air mass. The temperature and humidity differences in the upper layers are quite marked. The middle layer air in strong convective weather is very dry and especially very cold. The

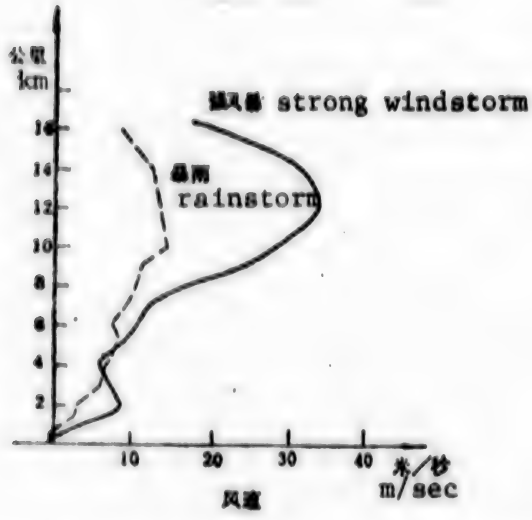


Fig. 4. Comparison of zonal wind shear in rainstorm (solid line) and strong convective weather (broken line) conditions

difference between the two may be 13°C. This is because when strong convective weather is developing there is marked level cold flow in the upper layer. During a thunderstorm, below 500 mbar the air is relatively humid, with the humidity characteristics differing by only a small amount above and below. Accordingly we find from the above analysis that rainstorms develop primarily in relatively deep warm, moist air masses, and their characteristics are determined by the nature of the warm moist air in the middle layer, and its horizontal distribution together with cold air; while strong convective weather clearly is governed by the strength of cold air in the upper and middle layers (or cold horizontal flow) and its vertical distribution relative to low-layer warm moist air.

4. Investigation of Medium-Scale Systems

Rainstorms and strong convective weather are medium-scale systems. Medium-scale analytical experiments were conducted in the lower Yangtze region in 1963-1965, yielding a good many useful results on the conditions for development, laws governing activity and relationship to weather of middle-scale systems.[24] In 1976, experimental medium-scale system observation experiments were begun in south China and the Xiangzhong [3276 0022] region.[25] These further deepened our knowledge of the basic nature and characteristics of medium-scale systems which affect our country (particularly medium-scale rain areas). There are four basic questions in medium-scale system research: 1. the structure and activity characteristics of medium-scale systems; 2. the mechanisms for origination, development and maintenance of medium-scale systems, the conditions under which individual cumulonimbus can organize into medium-scale systems, and the physical processes by which

mid-atmosphere lows and highs develop and maintain themselves; 3. feedback of medium-scale systems into large-scale environmental fields; and 4. the effect of a combination of middle-scale systems on their intensification or development of intense weather. Of these questions, the second is the most important.

There is still no uniformity of opinion on the question of initiating and organizing mechanisms of medium-scale systems. It is generally believed that lower-layer medium-scale or submeteorological convergence lines and gravity waves are important initiating mechanisms. Other factors and systems such as cold fronts, topography, low-atmosphere jetstreams, wind-speed discontinuity lines, dewpoint fronts, sea-to-land winds, density currents and the like can also initiate the development of windstorms and strong convective weather. Rainstorm initiating effects occurring at the points of intersection of discontinuity lines are even stronger. For example, analysis of windstorms in south China revealed that in the area where two ocean wind fronts moving inland intersected, extremely strong rain areas developed. Medium-scale cold air masses expanding from lower and middle layers to areas ahead of cold fronts also are able to initiate windstorms. In addition, when upper-air trough lines or shear lines coming from the west are superimposed on boundary-layer convergence lines, the development of middle-sized rainstorm systems could also be initiated.[26]

The most important matter with regard to the organization and development of medium-scale systems is explaining the formation of medium-scale lows, since medium-scale highs are generally believed to be the result of precipitation feedback. Currently there are three views regarding the formation of middle-scale lows: 1. surface medium-scale lows result from temperature rises induced by compensating subsidence flows below horizontal flow layers and above convective layers in front of medium-scale convective systems; 2. medium-scale lows are formed by subsidence movements produced by evaporative cooling at the top of developing cumulus clouds; 3. medium-scale lows are produced by release of latent heat of condensation. In addition, some believe that such mechanisms as warm horizontal flow can lead to upper-air heating and surface pressure drops and form medium-scale lows.[27] Currently it is impossible to say which of the above mechanisms is the most reasonable. The solution of this problem requires on the one hand observational instances and on the other performance of more quantitative calculations and numerical models. Once a medium-scale low is formed, lower-air convergence and water vapor supply increase, cumulus development is much more intense, and this can cause medium-scale highs to develop more rapidly and produce pressure pairs. Interaction with middle-scale lows and highs causes convective belts of medium-scale rain belts to propagate continuously forward and to promote the development of new convective clouds ahead, so that the medium-scale systems continuously propagate forward. The origination and development of medium-scale systems involves questions of medium-scale instability mechanisms; but theoretical study of the question of what scale of system interaction they are related to is still insufficient. In recent years some have used the "wave-type

second-condition instability" mechanism connected with gravity waves, to explain the development and structure of medium-scale systems; this has attracted some attention.

Observation and analysis make it clear that when medium-scale systems unite, marked development and intensification generally take place, along with violent weather.[28] Currently the mechanism by which the uniting of medium-scale systems leads to violent weather is not entirely clear. Some believe that when the systems combine their volume increases so that the heat of water vapor is transferred upwards and increases, and convective development becomes more intense. Some others believe that under certain conditions, when two thunderstorms in different stages of development come in contact, the upward airflow of the newer thunderstorm and the subsidence flow of the older thunderstorm can combine to form a strong convective system similar to a localized strong windstorm, producing violent weather.

5. Problems of the Dynamics of Rainstorms and Convective Weather

Research on the dynamics of rainstorms and numerical forecasting in this country falls into the following three areas: 1. dynamic modeling of large-scale weather development before and during the formation of rainstorms; 2. some medium-scale dynamic processes associated with rainstorms; 3. strong convective processes in cumulonimbus clouds.

Precipitation of 100 mm per day or more can be predicted using dynamic numerical modeling based on weather analysis.[29, 30] Comparison of results from models with different levels of detail indicates that in order to forecast rainstorm conditions, the detail size cannot be greater than 100 km, otherwise the relatively small-scale circulations which form rainstorms cannot be described. In the last few years, some rather profound research on moist baroclinic atmospheres begun by Xie Yibing [6200 5030 3521] et al[31, 32] makes it clear that when there is sufficient water vapor and the release conditions can be achieved, the most unstable wavelength of atmospheric length can be greatly contracted. If the instability wavelength is

$$L_m = \left(- \frac{a}{\theta_{se}} \frac{\partial \theta_{se}}{\partial_p} \right)^{\frac{1}{2}}$$

then provided the moist adiabatic lapse rate is about 0.7, L_m can be about half the value for dry adiabatic conditions. Although the real atmosphere is by no means saturated everywhere, this analysis based on extreme conditions shows that the effect of water vapor cannot be neglected, since it is extremely important in the formation of rainstorms limited to a small area.

Because the scope of the rainstorms is relatively small, even though the [Gelasihuofu] [phonetic] number which expresses the vertical acceleration in describing movement on this scale is less than 1, it is not so small

that it can be neglected, and accordingly the question of whether a nonstatic equation should be used has become controversial. Recent investigations[33] indicate that to describe correctly the gravity waves which play an important role in thunderstorm weather formation processes, nonstatic equations must be used, because the static formulas are extremely distorted in their description of gravity waves in the real atmosphere. Some nonstatic equilibrium formulas which can be used in studying rainstorms and convective weather are now being developed. After some technical difficulties are overcome (initial values, boundary values) and computer speed and capacity are increased, relatively great progress can be expected in numerical prediction of thunderstorms. Some progress has also been made in studies of violent weather which forms and develops as a result of gravity under conditions of the horizontally nonuniform stratification,[34] which can explain the fact that rainstorms are likely to develop to the right of and forward of lower air jetstreams.

The development of rainstorms and that of convective clouds are inseparable. Dynamic research on cumulonimbus clouds is an essential branch of rainstorm dynamics. In the early 1960's this country had already begun investigation of cumulus dynamics,[35] and the conditions for development of cumulus in differently stratified wind fields were analyzed. These analyses furnished the necessary conditions for current rainstorm dynamics modeling and numerical forecasting. But in the last 10 years, this country has not made much progress in numerical modeling of strong convective systems.

6. Analysis and Forecasting of Rainstorms and Strong Convective Weather

In recent years total energy analysis has been rather universally used in rainstorm and strong convective weather analysis;[36] it has revealed many early indicators of the occurrence of strong windstorms. Vertical instability energy analysis has already generalized some typical energy contour patterns which are connected with different convective weather intensities. Analysis of horizontally unstable energy fields indicates that thunderstorms and strong convective weather generally appear near a Q-type high-energy front. A good many units have also carried out diagnostic analyses of thunderstorm dynamics. Currently an objective dynamic diagnosis program applicable to rainstorm research which was designed by the Peking University Geophysics Department and the Jilin Provincial Meteorological Office is of great help in rainstorm analysis and research. Fig. 5 shows the vertical distributions of average vertical velocity (ω), divergence (D), vorticity (ζ) and water vapor convergence $\left(\frac{1}{g}\nabla \cdot vq\right)$ calculated by the revised continuous formula for individual rainstorms. It can be seen that the rainstorm area develops in a lower atmosphere convergence, upper atmosphere divergence, lower atmosphere positive vorticity, upper atmosphere vorticity area in which there is a strong rising motion in thick stratification.

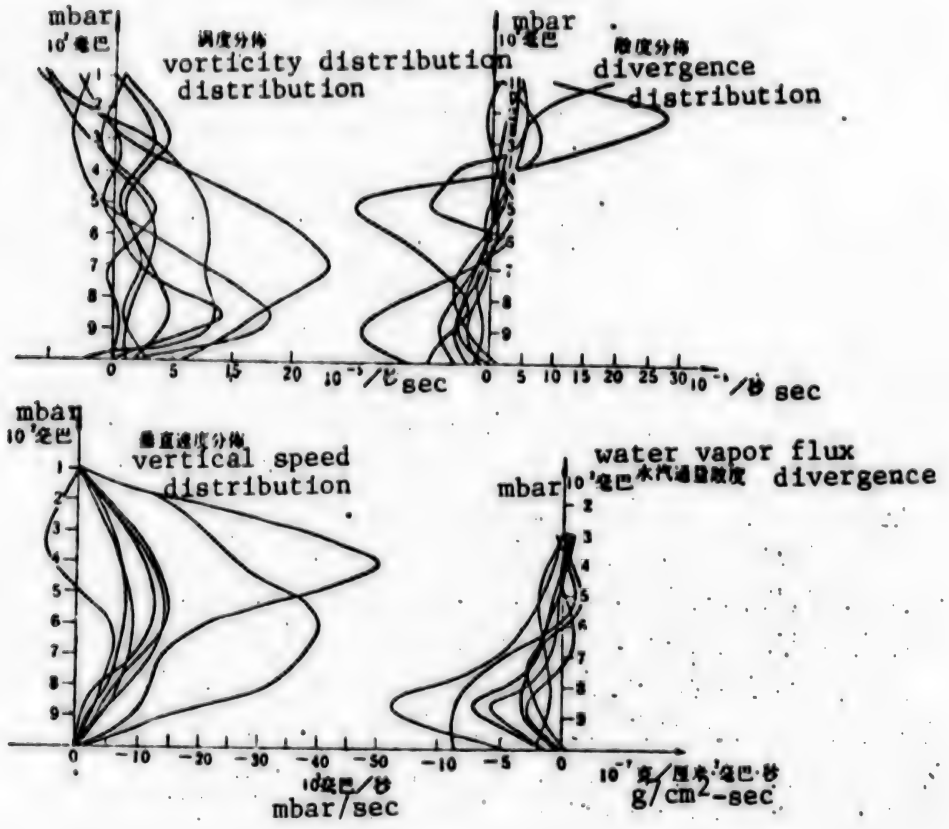


Fig. 5.

The maximum of the rising movement is generally located at 500-600 mbar, while the convergence and divergence maxima are at 900 and 200-300 mbar respectively. The water vapor convergence maximum is also at 850 mbar, and accordingly the low-layer water vapor convergence is the primary water vapor source for the rainstorm. Using the formula for omega, we can estimate the contribution of various physical factors to it. Analysis of many individual cases of thunderstorms indicates that vertical movement produced by latent heat of condensation accounts for 80-90 percent of the total value of omega. This means that the feedback effect from latent heat of condensation is very la_ge. But in strong convective systems, the effect on omega of latent heat of condensation is extremely small or nil.

Forecasting of thunderstorms and strong convective weather is a difficult problem, which involves the problem of interaction of weather systems on various scales. Currently the level of rainstorm forecasting here and abroad is not very high, and it is mostly limited to the short term (0-12 hours). Mid-range rainstorm forecasting currently is based on the

circulation background. In short-term rainstorm forecasting, there are currently three main methods. One is the empirical weather-map forecasting method, which is subdivided into two types: one is the weather pattern method, which uses combinations of features of weather systems which appear before or during rainstorms to determine the location of rainstorms; this is a method which is universally used in this country's weather stations, but it has the failing of taking insufficient account of the physical conditions that produce rainstorms. Sometimes with the same weather patterns, rainstorms will not occur, and when making a forecast it is frequently difficult to determine similarities. Moreover, it is generally difficult to report correctly rainstorm systems which are rapidly expanding or shrinking or whose speed is changing abruptly. The second weather map method is the location method. This primarily relies on certain physical conditions during the occurrence of rainstorms to determine the locations of rain areas. This method takes account of physical conditions which are related to rainstorms, and accordingly it generally achieved relatively good results. Particularly following rainstorm 7508, many units began to try the location method of rainstorm forecasting.[37] But one of the main shortcomings of this method is that many of the conditions and indicators which it uses are connected with the moment of occurrence. This means that rain locations of fast-moving systems generally cannot be reported accurately; accordingly the best method is to use physical conditions and indicators at the time of reporting. This problem can be solved by using numerical forecasting methods. In addition, some use lower-air jetstreams as the main indicator in rainstorm forecasting.[38]

The second method is the statistical method. Currently the pattern differentiation statistical method is in rather wide use. The advantage of this method is that it takes account of characteristics of all types of weather patterns and uses a group of factors to reflect a thunderstorm development process. Clearly this is much better than using a group of factors to reflect the process of development of all rainstorm types. But a shortcoming is that sometimes too many categories are distinguished and transitional patterns are not well handled. Sometimes differentiation analysis methods are used in rainstorm prediction. According to the central weather station's forecasting experience, predicted rain belts and precipitation centers are more or less in agreement with actuality, but there are still too many wrong forecasts. In particular, the correctness rate for rainstorms is not high.

The third method is a combination of numerical forecasting and dynamic-statistical prediction. We have already explained the numerical prediction method, which is currently in the research and experimental stage. The dynamic-statistical prediction method (MOS) is already in rather extensive use in various types of essential-factor forecasting abroad, and a certain degree of effectiveness has been achieved, but currently because in this country, specialists in numerical forecasting cannot yet provide sufficient physical factors, this work has not yet made much progress.

In addition, the provincial stations have accumulated a set of mid-range and short-range rainstorm forecasting methods such as the "nine line map" and a combination of many indicators and weather maxima. This is an excellent way to improve the correctness level of rainstorm forecasting.

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APPLIED SCIENCES

RESEARCH IN ATMOSPHERIC DYNAMICS, NUMERICAL WEATHER FORECASTING PROGRESSES

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[Article by Zeng Qingcun [2582 1987 1317] of the Atmospheric Physics Institute of the Chinese Academy of Sciences: "Progress in Our Nation's Research Work in Atmospheric Dynamics and Numerical Weather Forecasting"; this article was received on 16 May 1979]

[Text] Since liberation our nation's research in atmospheric dynamics and numerical weather forecasting has developed prosperously, and manu welcomed results have been achieved. A work force engaged in the study of dynamics and numerical forecasting work has been preliminarily formed at each locality of the motherland to study various dynamic problems closely related to the practice of synoptic forecasting and especially those questions that greatly affect our nation's weather. At the same time, attention has been paid to the study of problems of basic theory. Many achievements have also been made in the research of the theory of numerical weather forecasting and mathematical methods in our nation, and numerical weather forecasting operations have been partially established. Yet, generally speaking, our nation's work in these two fields is still relatively weak and should be greatly strengthened in the future to satisfy the needs of socialist construction.

There have been articles[1,2] summarizing the research achievements made prior to 1959 in our nation. This article will report on the progress in research work conducted over the past 20 years by the Atmospheric Physics Institute, and emphasis will be placed on the work of the most recent 10 years. Whenever information is available, this article has also included work done by others unrelated to the institute.

I. Atmospheric Dynamics

The scope of atmospheric dynamics is very wide. This article has divided the work into 12 aspects described below. Work concerned with questions in atmospheric turbulence and border layers, atmospheric circulation and dynamic analysis of synoptic systems has been discussed in separate articles of this publication and will not be mentioned here. In addition, since research in dynamics is closely allied with research in numerical

forecasting, and at the same time since dynamics research also utilizes many applications of the method of "numerical experiment," thus, under some situations, the discussion about work in dynamics will also touch upon some work in numerical forecasting. Under other situations, we have included part of the work in dynamics in the discussion of numerical forecasting.

1. Geostrophic Adaptation Process

Gravity and Coriolis force are the two most fundamental forces that function in atmospheric movement. In addition, the atmosphere can be compressed. These cause atmospheric movements shown in weather maps to possess frequently seen characteristics, for example, divergence and quasi-geostrophic equilibrium of large scale movements. The dynamic process that constantly drives atmospheric movement to sustain this kind of quasi-equilibrium state is the so-called geostrophic adaptation process. It is a basic dynamics process. The study of this basic process is a topic of basic theory but it also has very important practical significance. Since publication of the work by Ye Duzheng [5509 4648 2973],[3] our nation has conducted full-scale study of the geostrophic adaptation process and established systematic linear and nonlinear theories. Work done prior to 1965 has already been systematically summarized in the book by Ye Duzheng and Li Maicun [2621 7796 2625].[4] Work done after that and up to the most recent past is included in reference (5). Recently, Ye Duzheng and Zeng Qingcun [2582 1987 1317][6] also published an overall introduction. Therefore, only a list of the articles (3-24) and a brief introduction of the major results are given here.

Zeng Qingcun[8] (1963), Ye Duzheng and Li Maicun[4] (1965) used scale analysis to prove that in large scale movement, the adaptation process and the evolutionary process of synoptic systems can be differentiated on the time scale and in physical nature (stages in the process of atmospheric movement). Reference (8) also presented the concept of a "time border layer" to explain that a localized non-geostrophic disturbance can cause a temporary state, and the thickness of its "time border layer" is generally f^{-1} (f is the Coriolis parameter). Later many people(14-16, 18-19) also expounded on this concept and pointed out the stages of the evolutionary process of Rossby waves. Thus the multiple time scale characteristics(14-19) of atmospheric movement were proposed and studied. In reference (5), similar types of questions were discussed using the speed of energy dispersion.

After the adaptation process, the structure of the field of geostrophic winds is entirely determined by the distribution of vorticity of its initial position. Ye Duzheng[3] (1957) was the first to point out the existence of a critical level scale. When the scale of the initial disturbance is smaller than this critical value, the vortex field sustains itself and the atmospheric pressure field adapts itself to the situation, and vice versa. Later, Zeng Qingcun[7,8] (1960) and Chen Qiushi [7115 4428 1102][9] (1963) proved that this critical scale was the Rossby variable radius L_0. In an oblique pressure atmosphere, orthogonal structures also exert important effects[7], and the result shows that the low altitude shallow system is caused by thermal forces while the deep or high altitude system is caused by dynamic forces[7,20]. This is useful in explaining many processes of atmospheric dynamics.

Zeng Qingcun[8,21] first studied the problem of nonlinearity. He pointed out that the adaptation process and the evolutionary process of the field of air flow proceed simultaneously. Also, their mutual effects cause the flow field on the whole to remain in a geostrophic equilibrium state while non-geostrophic winds are constantly being generated. In addition, nonlinear processes also cause the divergence field and the vorticity field to match, i.e., the former adapts to the latter.[5] The conclusions described above have been further proven by numerical experiments conducted by Yuan Zhongguang [5913 6850 0342][22] et al. Cheng Qiushi[9,23] carefully analyzed the nature of the causes that establish and destroy the relationships of wind caused by heat in the two-tier model and connected it with the oblique pressure synoptic process and the unstable synoptic process.

Medium scale systems must be described in general by nonlinear equations. Ye Duzheng and Li Maicun[4] (1964) derived that at this time an adaptation towards a quasi-equilibrium state occurs and the flow line and the "isoenergy line" ar parallel. Zeng Qingcun[5] also pointed out that when certain conditions are satisfied, the isolated medium scale system will finally adapt completely. This can explain the medium and small scale synoptic systems' quasi-linear structure or quasi-symmetric vortex structure. In the process of nonlinear adaptation, the law of conservation of positional vorticity and the distribution of the vorticity of the initial position are still the determining factors. The flow lines after adaptation are parallel to the isopotential vorticity line. Li Maicun[15] also obtained the same results.

In oblique pressure atmospheres, even when linear equations are used to describe them, processes of geostrophic adaptation also occur because of the existence of the mechanism of dispersion of disturbing energy into space.[5,13] This explains the quasi-geostrophic property of the superlong wave scale movement on the earth's surface and the quasi-belt-shaped structure of circulation above the stratosphere. Zeng Qingcun[5] also studied the adaptation processes of regions near the Equator and their characteristics. Chao Jiping [1560 4764 1627][24] proved there is also static equilibrium adaptation. Zhang Kesu [1728 0668 5685][10] discussed the problem of quasi-geostrophic equilibrium under the presence of an external heat source and viscous expenditure. Luo Qiren [7482 0796 0088][11] and Zeng Qingcun[5] discussed the relationship between the processes of frontal genesis and the processes of adaptation. Lu Keli [0712 0344 0448][220] discussed the effect of the bottom air flow of a shear upon the processes of adaptation.

2. Mutual Effects of Nonlinearity of Movements of Various Scales and the Process of Rotational Adaptation

The study of the mutual effect of various scales of movement is significant both in basic theory and in practice. In a rotating atmosphere, not only is there a process of transference of energy from large scale movements to small scale movements but also a reverse process. For example, the convective movement of large cumulus clouds sustains a medium scale vortex and typhoon circulation while the feedback of energy of planetary waves towards superlong waves sustains the superlong waves and the belt-shaped circulation. This section will only discuss the mutual effects in the process of large scale movements.

Fjortoft[25] first discussed changes in the energy spectrum of the absolute movement of two dimenaional incompressible fluid bodies on the earth's surface (not considering the effect of earth's rotation). At this time "conservation of the average scale" occurs. Energy of the long wave (L) and energy of the short wave (S) are transferred simultaneously to the medium wave (M) or vice versa ($L \rightarrow M \leftarrow S$ or $L \leftarrow M \rightarrow S$). Zeng Qingcun[5,26] obtained the following after taking into account earth's rotation. "Quasi-conservation of the (medium) scale" occurs only at the meridian. On the rotating global surface, planetary scale atmospheric movements do not possess isotropy, and along latitudinal circles there may also be a process $L \leftarrow (M,S)$. These conclusions are closer to actuality. Lonquet-Higgins et al[27] simplified the work in reference (25) to a planar problem and discussed the special solution of the mutual effects of three waves in the quasi-geostrophic model. Wu Rongsheng [0124 2837 3932][28] used the same method and reached the conclusion that the energy of long waves under the mutual effects of three waves cannot entirely participate in the energy circulation process.

In addition, Ye Duzheng and Chen Xiongshan [7115 7160 1472][29,30] discussed the mutual effects of belt-shaped circulation and non-belt-shaped disturbance. The evolutionary change of the disturbance was first solved by linearized equations, and then the result was used to compute its mutual effect and the feedback to the belt-shaped circulation. They pointed out that the mutual effect of the disturbance is an important mechanism in the formation of a blocking high pressure system. Ye Duzheng and Fang Zongyi [2455 1350 5030][31] pointed out that after considering the mutual effects, the stable westerly wave can become unstable and may also invert.

Using the original equation to study mutual effects, one can obtain even more profound results. Zeng Qingcun[5,26] pointed out that on a rotating global surface, when certain conditions are satisfied, the energy of non-belt-shaped disturbances (planetary wave) and the energy of gravitational and inertial waves can finally be completely absorbed by the latitudinal circulation, i.e., adapting to the rotation of the earth, and thus it is called "the process of adaptation to rotation." For example, the major condition in the two dimensional orthogonal pressure flow over the entire global surface is that the isoline of the positional vorticity has only two centers. In an oblique pressure atmosphere, there must be the additional condition that there is no advection over land surfaces. If there are more than two vortex centers, then there will be no trend towards the belt-shaped latitudinal circulation. This mechanism can better explain the leading causes of "negative viscosity," index circulation and the process of medium range weather changes. We[32] also conducted many numerical experiments and the results coincided with theory. It must be pointed out at the same time that the use of the quasi-geostrophic model and planar approximation frequently will not produce a process of adaptation to rotation. It is possible to obtain a pseudo energy circulation.

3. Atmospheric Wave Motion

Large scale disturbances in the atmosphere can generally be divided into fast waves (gravitational-inertial waves) and slow waves (its actual nature is a flow field consisting mainly of a rotational motion, and even a closed vortex may also be included in this category). Zeng Qingcun[5,13] studied these in more detail and pointed out that in the mesophere (50 to 90 kilometers high) there may exist gravitational-inertial waves of very short vertical wave lengths. Complete and satisfactory results were also obtained in the classification of small disturbances on the surface of the globe[5]. In addition, reference (5) and Du Xingyuan [2629 5887 6678] et al and Li Maicun et al also discussed the problem of classification of wave motion in the Equatorial region. In reference (5), the characteristics of the various kinds of waves were also studied from the point of view of energy dispersion, and it was pointed out that the most frequently existing and most easily discoverable wave lengths are waves with zero group velocity.

In medium and small scale movements there are also sound waves and convection (convection is actually a vortex motion, but generally buoyancy must be taken into consideration). Chao Jiping,[24] Zhang Kesu and Zhao Xiaoping [0719 2556 1627] and Ye Duzheng and Li Maicun[4] proposed a method of filtering out sound waves while not seriously distorting the remaining medium and small scale movements. Li Maicun emphasized the study of nonlinear gravitational waves. He and Zhou Xiaoping[29] also studied the relationship between gravitational waves and rainstorms. Nonlinear gravitational waves can form discontinuous lines--"windstorm lines"--and strong convergence and convection are created, forming strong windstorms and rainstorms. Chao Jiping et al used the two-tier model's linearized equations to discuss the characteristics of propagation of gravitational-inertial waves and used them to explain the possibility that thunderstorms can propagate in a direction against air flow and the phenomenon of "reasonance."

Zeng Qingcun[5] studied the mutual effects between the fast waves and the vortex flow field and reached the following conclusion: In the process of propagation, an increase in the energy of the fast wave is accompanied by a shortening of the wave length. When the energy is absorbed, the wavelength lengthens. Fast waves that propagate into cyclonic regions and regions of strong winds are frequently absorbed. In addition, Xue Fanbing [5641 0416 3532] studied atmospheric tidal movements caused by the motions of the earth and moon. He pointed out that the lunar and solar tidal difference frequency wave and the polar shift wave are low speed propagating waves. When propagating downward they have a large capability to magnify and can affect synoptic systems. Some possible applications were also discussed.

The scope of the subject of wave motion is very wide. Other related questions will be included in each of the following sections.

4. Propagation and Evolution of Planetary Waves

Planetary waves are also called long waves or Rossby waves. They are slow waves. They are a kind of simple models describing high altitude synoptic

systems of troughs and ridges. The propagation, evolution and energy relationships of planetary waves are some very important questions. Ye Duzheng et al conducted extensive studies. The many works described in Sections 2 and 3 also belong to this field. In addition, Ye Duzheng[20] (1949, 1958) and Zeng Qingcun[5] more systematically discussed the process of energy dispersion of planetary waves and upstream effects. Sun Shuqing [1327 3219 3237], Chen Longxun [7115 7127 8113] and Ye Duzheng et al discussed the vertical propagation of disturbances and the mutual effects between the troposphere and the stratosphere, and the concept of "refraction index" was utilized. They obtained the following results: Under vertical distribution of certain westerlies, superlong waves can propagate upwards and downwards through the stratosphere.

Although the problem of instability is important, the deformation of flow fields and such evolutionary processes are even more general and more realistic problems. Ye Duzheng and Chen Xiongshan used the quasi-geostrophic two-tier model's linearized equations and derived that repeated addition of the south and north troughs and repeated addition of disturbances of high and low layers can often create rapid and violent developments even surpassing the results of oblique pressure instability. Later, Ye Duzheng (1964) first proposed and studied the evolution of small disturbances under wave-like bottom air flows, expanded the scope of study of the instability theory, and obtained many new conclusions including the mutual effects of disturbances. Lu Peisheng [4151 0160 3932] et al further discussed the general problems of evolution of small disturbances under non-advective and curved air flows. He concluded that when disturbances develop, the wavelength lengthens, and when disturbances weaken, the wavelength shortens. From this, some models of evolutionary processes were devised and it was pointed out that the so-called retreat of superlong waves is frequently the result of widening or eastward shift of the long wave.

After the spiral structure of planetary waves was shown by weather satellite photos, it became the center of attention of meteorological scholars. Chao Jiping and Ye Duzheng (1977) were the first to study the dynamics of spiral planetary waves in an orthorginal pressure atmosphere and pointed out they play the major role in sustaining the physical patterns of atmospheric circulation. Liu Shishi [0491 1709 6624] and Yang Dasheng [2799 1129 0581] made further studies and expanded the studies to include oblique pressure atmospheres. The method and conclusions in reference (46) can also be suitably used to discuss spiral waves.

5. Instability of Disturbances and Evolution of Synoptic Systems

Do high altitude troughs and ridges and ground surface cyclones develop? These are matters which the weather forecaster is very concerned about. The theory of instability of disturbances is the first theory to study this question from one side. But since the 1960's, progress has not been great except for the theory of "instabilities of second category conditions" proposed internationally in specialized studies of tropical synoptic systems. Xie Yibing [6200 5030 3521] and Yang Dashen et al of our nation's Beijing

University studied the instability of the tropical easterly air flow and concluded that the instability is related to the size of the south and north shears of the bottom air flow and the latitude and the wavelength of the disturbance. Unstable waves have shorter wavelengths. These results were combined with the question concerning the development of typhoons. Ye Duzheng et al discussed the instability of superlong waves and pointed out that the controlling factors are mainly static stability and the vertical shear of wind speed.

Zeng Qingcun[5] utilized the original equations for orthogonal pressure atmospheres and derived the general formula for the criterion of instability of small disturbances which are repeatedly added onto the bottom flow of advective and straight shears. The general formula is also suitable for high, middle and low latitudes. If the base flow is $\bar{u} < \sqrt{\bar{\phi}}$, it becomes the generalization of the criterion of orthogonal pressure instability developed by Guo Xiaofeng [6753 2556 1526]. But under unstable conditions, fast waves may also develop. Secondly, when $\bar{u} > \sqrt{\bar{\phi}}$, "super high speed" instability occurs and non-geostrophic winds develop violently. The two described above are called "non-geostrophic instabilities."

To discuss the question of instability of small disturbances under non-advective and curbed bottom air flows it seems that only the methods described in references (5), (45) and (46) can be used. In addition, Liao Dungxian [1675 3159 6343] used nonlinear equations to discuss the rate of time change (tendency), and pointed out that since curvature vorticity and shear vorticity are interchangeable, a large deformation of the flow field can be obtained and the criterion of linearized instability need not be satisfied. Also, materials on instability have also been included in the several sections above.

6. Superlong Waves

Superlong waves are closely related to medium and long-range weather changes. A lot of dynamics research work is being done in our nation also. Since superlong waves are closely related to heat sources and topography, the work in dynamics has generally taken the effects of these forces into consideration.

Liu Ruizhi [0491 3843 5347] et al introduced dispersion of the entire stratum to control the moving speed of superlong waves. Zhang Jijia [4545 1015 0857] used the multiple strata quasi-geostrophic model to discuss in detail the effects of each factor upon the evolution of superlong waves.

Zeng Qingcun[5,57] proposed a revised quasi-geostrophic model that takes into account both superlong waves and long waves under spherical coordinates, and pointed out superlong waves should be divided into two major categories. One category includes superlong waves with greater longitudes and the other category includes those superlong waves of mainly latitudinal circulation. They possess different dynamic properties. Li Maicun and Chou Jifan [0010 4764 5400] et al arrived at the same conclusion using β plane approximation, and pointed out the Burger type superlong waves belongs to the high

modality type in vertical structure. Li Maicun and Yao Dirong [1202 2769 2837] also studied superlong waves and long waves of tropical zones and pointed out that longitudinal superlong waves may be a mixture of slow waves and gravitational-inertial waves.

Zhu Baozhen [2612 2128 4176] (1964) used the two-tier quasi-geostrophic model to discuss the effects of large topography and heat sources upon superlong waves and pointed out these factors can cause superlong waves to deepen within fixed geographical regions and the amplitude of superlong waves changes in 10-30 day cycles. Later, Chou Jifan et al and Chen Qiushi also discussed similar problems. Li Chongyin [2621 1504 6892] and Zhu Baozhen (1963) used the three-tier quasi-geostrophic model and spectral decomposition (taking only a very few number of waves) to study the formation and nature of off center polar circling vortices, and pointed out the large topography of the northern hemisphere and the off center asymmetric distribution of heat sources are the reasons causing off center disturbances. It is worth pointing out that according to the theory of rotational adaptation, it can also be derived that there must be thermodynamic factors to sustain an off center vortex. Xu Youfeng [6079 2589 6265] et al used a method basically similar to that expounded in reference (62) and took into account the effects of radiation heating and heat sources of the ground surface.

Zeng Qingcun[5] pointed out that the superlong wave can be basically viewed as a passive system. It is controlled by topography, heat sources and energy feedback of long waves, and it adapts to these factors. To filter out the long waves and to discuss singularly the properties of superlong waves may not be possible.

7. Long Range Evolutionary Process and Quasi-ordinarily Fixed Flow Fields

Problems in these aspects are often called problems of atmospheric circulation. In the 1950's, Ye Duzheng, Gu Zhenchao [7357 7201 3390] and Zhu Baozhen had made important contributions[20] towards the establishment of a dynamic model for ordinarily fixed atmospheric circulations in East Asia. Later, Xie Yibing and Chen Shoujun [7115 0649 6874] et al also studied the question of ordinary fixed flow fields. Reference (64) derived the distribution of longitudinal circulation and wind speed of westerlies under oblique pressures when a fixed heat source and horizontal turbulance are given, and generalized Rossby's hypothesis (1947) of sideways mixing of vortices.

Gu Zhenchao (1958) was first to use the methods and concepts of cybernetics to study seasonal change, annual change and questions of long range changes in atmospheric circulation, regarding the atmosphere as a constantly self adjusting system under the input of solar radiation. Later Chen Xiaogshan utilized the linearized two-tier quasi-geostrophic model for some concrete computations and discussions. Zhu Baozhen et al used the two-tier quasi-geostrophic model and discussed mutual adjustment of heat source and motion, and concluded that under linear conditions, the adaptation of the isobaric surface to the heating field is extremely rapid, generally requiring only

about 10 days. Chen Xiongshan continued work in this aspect. He utilized the two-tier quasi-geostrophic model to illustrate annual changes by choosing five points in the north-south direction and three waves along the latitudinal circle. The results were similar to actuality.

Since the 1970's, the Atmospheric Physics Institute has launched studies in experiments to simulate atmospheric circulation. The studies considered the effects of heat sources and topography and obtained many important results in the formation of the East Asia trough, the Qinghai-Xizhang high pressure system and the subtropical high pressure system, their changes and stability. (This publication has published other articles about these.)

In addition, questions concerning the mutual effects of weather systems over land and weather systems over the sea have also been studied in combination with long-range numerical forecasting problems. Movement of the atmosphere itself could only temporarily be considered in simpler terms, and various heat sources and heat convergence are represented by simple parametric forms, and a type of planetary waves with a cycle of about 3 months was obtained. In addition, and under appropriate conditions, the state of atmospheric movement is frequently an adaptation to oceanic temperature fields but contrary situations also exist.

8. The Effects of Topography

The study of dynamic and thermodynamic effects of topography has achieved many results in the 1950's in our nation. In the 1970's, simulation experiments were studied as described above. We also want to mention here that simulation experiments concerning the question of not ordinarily fixed flow fields were also conducted, for example, studying the movement of the southwest eddies that seriously affect China's weather. Besides these, still other works discuss the work to explain ordinarily fixed flow fields. Still other works combine superlong waves with atmospheric circulation as described above. The rest of the work is combined with numerical forecasting and emphasizes the study of not ordinarily fixed flow problems (mostly using the quasi-geostrophic model), instantaneous change in the flow field caused by topography, or the effects upon the movement of synoptic systems.

Zeng Qingcun[5] used scale analysis to analyze the problem of the effect of topography in the original equations. He pointed out that in talking about the effects of large scale topography, three situations should be differentiated. They are low topographic disturbance, circling air flow due to high topography and climbing over high topography. In the two former situations, the process of change of the field of flow is quasi-geostrophic. But in climbing over high topography, the characteristic time scale is very short and quasi-geostrophic approximation cannot be used. This coincides with the occurrence of violent synoptic changes when the synoptic system moves out of the plateau. Chou Jifan et al used a method similar to that described in reference (8) to prove "the process of adaptation of the flow field to topography"--which tends towards circling flow.

Some work was also done in the discussion of the effects of medium and small topographies. Chao Jiping et al discussed the conditions in a two-tier even mass fluid body in which topograp' · causes air flow and spontaneous change of atmospheric pressure. L: Yi [2621 5065] and Du Xingyuan et al conducted numerical experiments with nonlinear leeward slopes and showed that they were closely related to the distribution of rainfall in the Taihangshan region. Zeng Qingcun (1965) discussed the physical causes of leeward slopes and three-dimensional orographic ascent, and pointed out that in the vertical cross sectioned two dimensional problem, buoyancy causes leeward slopes and these cannot be approximated by quasi-static equilibrium. But in the three dimensional problem, "boat shaped" orographic ascent can be created without any dependence upon buoyancy. In the actual atmosphere, three-dimensional orographic ascent is even more frequently seen.

9. Dynamic Processes in Wet Oblique Pressure Atmospheres

Condensation heating is the most important source of heat in atmospheric movement. The mutual effects between it and atmospheric movement should be a very important subject of study in atmospheric dynamics. But because of the complexity of the problem, not much research has been done in this regard. In recent years, Xie Yibing of our nation's Beijing University, Lei Yushun [7191 7183 7311] and Wang Liangmin [3769 0357 6900] of the Central Meteorological Bureau and Luo Huibang [5012 2585 6721] et al of Zhongshan University began research in this regard, and they have obtained encouraging results. The basis of these efforts is to begin from the energy viewpoint, taking into consideration various forms of energy which are interchangeable. Thus inner energy, potential energy, latent heat and kinetic energy are unified, and based on this foundation, to establish forms of dynamic equations and their corresponding methods of analysis. Preliminary experiments in actual work have shown that forecasts of strong windstorms and rainstorms can be made. In addition, Li Maicun studied the effects of condensation and gravitational waves upon the formation of rainstorms. Other work is combined with the study of numerical forecasting and of advection.

10. Atmospheric Advection

Advection is an important form of atmospheric movement. Heat transfer in the lower layers of the atmosphere, formation of non-stratus clouds and the process of rainfall are all related to advection. Comprehensive observation of cumulus clouds and corresponding dynamic studies have been launched in our nation and many achievements have been realized. Concerned work has been completely summarized in the special work by Chao Jiping and Zhou Xiaoping. Only work following theirs is presented here. Some work has been done to search for a tool for instability analysis to be used in forecasting thunderstorms and advective rains, for example, the work described in references (90) and (93). Others have discussed the reaction of rain upon air flow. Zhou Xiaoping and Zhang Kesu et al have been working hard to establish equations that better describe advective movements. At present they are engaged in combining forecasts of thunderstorms with numerical experiments.

Large scale advection is also very important. The Atmospheric Physics Institute has discovered in simulation experiments that when heating on a plate without rotation, only single cell advection that increases linearly with time occurs, but when heating intensity is large enough and when the rotating angular speed is appropriate, a low frequency and large amplitude advection is formed called "inertial advection." These are very similar to the advective systems in summer over the Qinghai-Xizhang Plateau. The simulation group also formulated an appropriate theoretical explanation for this phenomenon. The interesting thing is that even when using quasi-static approximation, the above differences could also be approximately reflected.

11. Typhoons and Vortices

Zhang Jieqian [1728 2212 6692] and Wei Dingwen [7614 7844 2429] et al utilized infrared heating and successfully simulated the formation of typhoons and their structural and moving patterns on a rotary plate. The results were very similar to typhoons in the atmosphere. For example, the eye of the typhoon, the cloud wall and spiral cloud belt have all been simulated. Such phenomena as the typhoon center splitting into two centers as it passes through Taiwan and the circling around to the right and acceleration of the typhoon when encountering a highland have all been simulated. Corresponding theoretical research work is also worthwhile. In addition, Chen Qiushi used inertial instability to explain the formation of typhoons while Xie Yibing et al and Yang Dasheng et al considered it as a result of shear instability in the tropical convergence zone. Many others used synoptic methods to study the causes of typhoon formation.

Wu Zhonghai [0702 0022 3189] discussed the paths of dual typhoons and the movement and deformation of tornado groups and found that duel typhoons do not combine. They can only approach each other and spin. In addition, Yang Dasheng discussed the sustaining of low eddies by the planetary border layer and by the structure of circulation as well as conducted studies in the mechanisms that bring about rainstorms.

Vortex is a frequently seen and very important form of atmospheric movement. The study of vortex dynamics must be intensified in the future.

12. Some Fundamental Problems in Mathematical Physics

We all studied some fundamental problems and questions of mathematical methodology. In reference (5), research results in these aspects and many questions of fundamental dynamics described above have been systematically summarized. Zeng Qingcun[5,8,102] studied the characteristic parameters that determine the nature of large scale movement, and pointed out that the ratios $\varepsilon = (f_0 T)^{-1}$, $M_a = U/c_0$, $\mu^{-1} = L/L_0$ between the movement's characteristic time T, characteristic speed U, characteristic length L and the corresponding characteristic values f_0^{-1}, c_0 and L_0 determined by the external environment are the three fundamental characteristic parameters. When there is topographic influence, the parameter $\Delta \quad \tilde{p}_s/p_0$ or "the degree

of topographic disturbance" must also be taken into consideration, where $\Delta p_s \equiv p_0 - \tilde{p}_s$, p_0 is the standard sea level atmospheric pressure and p_s is the characteristic atmospheric pressure on the highland. Gu Zhenchao used a similar principle and studied the characteristic parameters that determine medium and small scale movements. Later, Zhang Kesu generalized the work of reference (102) to static equilibrium. Zeng Qingcun also pointed out that the expansion of ξ is asymptotically convergent and he used the concepts of functional analysis to study the problem of expanded convergence.

In establishing the dynamic model, it should be based on actualities of meteorological phenomena. At the same time, in the course of establishing a theoretical model, reasonable inspection must be performed so that it will be physically reasonable and mathematically appropriate. Zeng Qingcun[5] paid more attention to this problem. He pointed out that the correct representation of a vertical border condition should be that the total amount of energy of the air column is limited, and he proposed the method of expansion of small disturbances along the vertical coordinates. Studies were also conducted in determining whether the initial and the boundary values of the generalized solutions of each model complied with the definition. In addition, Shi Zongbao [4258 1350 1405] studied the compliance of dynamic equations with the definitions in non-static equilibrium approximations in initial and boundary value problems. Chou Jifan et al discussed the uniqueness of the solution of the quasi-geostrophic model.

In dealing particularly with problems of dynamics on the surface of the globe, Zeng Qingcun[5] constructed the definitions of generalized functional space on a spherical surface and the generalized vector space on a spherical surface, and he provided their expression theorem, embedding theorem and expansion theorem. Upon this basis, the existence, the uniqueness and the stability of the solution to the initial value problem of the set of Laplace tidal equations were proven and the formula for the expansion of the characteristic wave motion was given.

II. Numerical Weather Forecasting

Research in numerical weather forecasting began relatively early in our nation. Comrade Gu Zhencao began research work as early as the 1950's. Later, many others also engaged in such research, the scope widened and many theoretical achievements were realized. Now, efforts are being made to build up our nation's numerical weather forecasting operations.

1. Establishment and Application of the Simplified Model

Since 1959 a lot of research has been done and applications are still being made of the simplified models (orthogonal pressure quasi-dispersionless model, quasi-geostrophic model). References (106) and (107) proposed and applied the quasi-geostrophic model to spherical coordinates. Reference (113) is a model between the quasi-geostrophic model and the quasi-equilibrium

model. Dong Keqin [5516 0344 0530] et al utilized the orthogonal pressure model and revised it for use in forecasting typhoon paths. The results were good, and the method has been used in actual operations. In addition, Zhang Xifu [1728 6932 4395] and Liu Ruizhi conducted many test forecasts of the evolutionary process of blocking high pressure systems. Nanjing University also experimented with the effect of medium latitude flow fields upon low latitude flow fields.

Wang Zonghai [3769 1350 4110] and Liao Dongxian studied a solution using equilibrium equations. Reference (116) proposed the algebraic method of rotational substitution and repeated addition. It yielded good results. Zeng Qingcun[7] proposed that using the actually measured wind field as the initial field for the quasi-geostrophic model can improve forecasts.

Gu Zhencao was the first to state the importance and the possibility of introducing historical data into the forecasting model.[2] Later, Chou Jifan (1962), Zheng Qinglin [6774 1987 2651] and Du Xingyuan et al proposed a concrete method of expression for the quasi-geostrophic model. To more effectively utilize historical data, reference (119) used the empirical orthogonal function and the results were acceptable. Wang Yaosheng [3769 5069 3932] introduced into the original equation the function of external force deviation determined by actual experience.

2. The Design and Application of the Format of Computation of the Original Equations

In 1960 Zeng Qingcun successfully designed and tested computational formats for solving the original equations for large scale applications. These were the so-called "semi-concealed format" (at the time it was called "semi-obvious format") and "completely concealed format." Later the "semi-concealed format" and its various variations (actually the differences were not great) were widely used domestically and abroad. Chen Xiongshan et al expanded it to three strata, and included the effects of topography and condensation heating. This format has been used domestically in forecasting operations. In addition, Zeng Qingcun, Ji Zhongzhen [1323 0112 6297] and Yuan Chongguang (1962-1965) directly solved the three-dimensional elliptic equation of the "semi-concealed format" and the "completely concealed format" according to reference (102). This seemed to make multiple strata forecasting relatively easier.

As early as the beginning of the 1960's, our nation had proposed that assuring properties of the whole in approximation computations is an important method in designing and computing the stable format. Liao Dongxian (1964) and Guo Benyu [6753 2609 3842] (1965) both designed formats based on instantaneous conservation of total energy and the squares of total positional vorticity for the two dimensional vorticity equations. The format of reference (127) was more complete than that of Arakawa. In 1964-1965, Zeng Qingcun and Ji Zhongzhen et al designed a difference format for the original equations of energy conservation using the difference method for time and space (under some situations this is the "generalized energy conservation format"), and "versatile substitution" was introduced so that some parameters and computational methods could be adjusted to

raise the precision and the stability of the computations. In the spacial difference format, the Lilly format (1965) is only a special case of our method (it should be pointed out that the formats in (126), (127) and (129-(131) and the formats in (128) and (132) were independently and almost simultaneously designed). If the versatility parameters can be alternately adjusted in temporal step-lengths, then a split step-length format can be obtained, similar to the Marchuk plan, but more versatile. Reference (134) provides a systematic summary of the formats described above, the theory of their design and computational formats as well as other questions in numerical forecasting. In addition, Chen Qiushi also suggested a kind of obvious split step-length format based on the divisibility of the adaptation process and the evolutionary process. It should be pointed out that Wang Zonghao had already applied the split step-length method to the orthogonal vorticity equations as early as 1963. Zeng Qingcun (1962) started out from the divisibility of the time scale in the evolutionary process and the turbulance process and proposed to calculate several evolutionary processes first and then to calculate a one-step turbulance smoothing process. This is exactly equivalent to the method of adding a smoothing operator in ordinary forecasting processes. Zeng Qingcun (1962) and Wang Zonghao also proposed the three dimensional and two dimensional windward differential formats and proved their computational stability. Another format by Wang Zonghao et al (1964) used the characteristic wedge cone to treat air flow that pierced through the borders and obtained better results.

Zhou Xiaoping, Zhang Xuehong [1728 1331 3163] and the Mathematics Department of Wuhan University and the Wuhan Meteorological Observatory experimented with the four-tier model of equal regions for forecasting. Topographic effects were included and the model was used to forecast changes in atmospheric pressure at the ground surface. The Atmospheric Physics Institute's medium range forecasting group's Zhu Baozhen, Chen Jiabing [7115 0857 6333], Zhang Daomin [1728 6670 3046] and Luo Meixia [7482 5019 7209] et al designed a three-tier model and considered the effects of topography, condensation radiation and thermal sensitivity, and conducted a lot of research and experiments with these physical factors. This model has been expanded now to five tiers and matched with the localized and regional five-tier model of the Beijing University and will be used in forcasting operations. The tropics numerical weather forecasting cooperation and coordination group designed a one-tier model and a four-tier tropical model and successfully used them to make actual forecasts. Qian Yongfu [6929 3057 3940] et al and Liu Jinda [0491 6855 6671] developed a format that emphasized the method of computation of atmospheric pressure gradient forces in the presence of topography.

Zhen Qinglin designed a seven-tier spectral model for the original equations which will be used in forecasting operations. In addition, Liao Dongxian et al designed a difference format for the original hemispherical energy conservation equations with four grades of precision.

The Shanghai Meteorological Observatory cooperated with the Nanjing University and utilized the orthogonal original equations to forecast typhoon paths. Zhu Baozheng et al utilized the three-tier model described above to study cyclones of the Changjiang and Huai rivers. Ji Liren [4764 4539 0086] studied the genesis of the summer shear line. Du Xingyuan

and Xu Youfeng studied the use of numerical forecasting results to forecast leeward slopes. All achieved good results.

3. Problem of Computational Mathematics

The study of the problems of computational mathematics occupies a very important position among numerical weather forecasting methods. Designing a computationally stable, time saving and also relatively accurate format is in itself a central problem in computational mathematics. These aspects have been touched upon in the two sections above. Wang Zonghai has done a lot of valuable work in raising computational speed, in the calculation of advective terms and in solving equilibrium equations. Liao Dongxian exerted efforts in designing high level precision difference formats. Ma Jipu [7456 0679 3302] proposed the use of generalized functional methods to construct irregular grid difference formats. Applications of the method of finite elements and sample strip functions were also studied, and it was proven that the Arakawa format was only a special case of the method of finite elements. Some work has attempted to introduce a corrective factor into the ordinary difference format with two grades of precision to raise precision. Recently, a lot of work is being done in the design of spectral models. Chen Xiongshan and Xing Runan [6717 1172 2809] also experimented with various plans of spectral models and high speed Fourier transform. The method may be one of the fastest at present.

Zeng Qingcun, Ji Zhongzhen, Liao Dongxian and Guo Benyu also studied theoretical problems in computational mathematics related to problems in numerical forecasting. Guo Benyu studied in detail the two-dimensional vorticity equation's difference format, proposed a kind of generalized stability definition, and gave an estimated value of the solution for the initial value and the stability of disturbance on the right side, and a strict estimated value of the effects of boundary shapes and boundary conditions upon the solution. These methods are also very meaningful in computational mathematics. Zeng Qingcun and Ji Zhongzhen studied the general problems in calculating stability using the computational format of the equations of evolutionary process (in mathematics they are called "developmental equations"). Some theorems were given. In particular, the problem of nonlinear computations of instability was profoundly studied. It was pointed out that only a format that can satisfy energy conservation or the estimated values of the numerical range of the amount of energy significant in temporal and spacial differences can completely eliminate the instability of nonlinear computations. Liao Dongxian et al studied the formulation of side boundary conditions.

Zeng Qingcun (1965) started out from the point of view of mathematical physics and analyzed in detail the mechanism that causes computational disorders (including the special computational instability) when the step-length is finite. He pointed out that the parasitic wave is caused by three mechanisms, abnormal frequency dispersion properties, abnormal transformation of the energy spectrum and destruction of the energy relationship, and he proposed a specific method to overcome them. Liao Dongxian

and Zeng Qingcun also analyzed in detail the reasons that the finite difference method causes the moving speed of synoptic systems to slow down. Zeng Qingcun (1962), Zhang Yaoke [1728 5069 4430] and Wu Rongsheng also studied the smoothing operator.

4. The Problem of the Initial Field and the Problem of Four Dimensional Analysis

In using the original equations for numerical forecasting, the method of treatment of the initial field is a very outstanding problem. The actually measured wind field and temperature and pressure fields always contain errors. If these are not properly handled, pseudo gravitational-inertial waves will necessarily emerge and cause computational disorders. Reference (120) was the earliest to propose the use of geostrophic wind as the initial wind field. Later this was widely used domestically and abroad. The method of expansion of small parameters can also be used to eliminate fast waves.(5,121) Liu Ruizhi et al experimented with second order approximation of equilibrium equations and the results were better. Another method is the direct use of actually measured wind field to calculate the flow function and to compute the altitude field from it(7,150). The results of this experiment were not bad.

Simultaneous use of actually measured wind field and the temperature and pressure fields is also workable. One method is to appropriately adjust the versatile parameters so that incoordination between the wind field and the pressure field gradually disappears in the process of forecasting. Other ways all require some treatment of the initial field. Zeng Qingcun (1965) pointed out that observational errors of the wind field and errors in the temperature and pressure fields are all similar accidental errors. Thus the key is to handle well the short wave portions of all the fields. For this, an optimization plan was suggested to solve the "generalized isoperimetric problem" and thus obtain a well treated initial field. This method can also be mixed with the method of adjustment of versatile parameters in application. Liao Dongxian, Zheng Xingli [6774 5281 4409] et al and Wang Xiaolin [3769 2556 2651] et al proposed some other variation methods to improve the Sasaki method. Zhou Jiabin [0719 1367 2430] et al and Ni Yunqi [0242 0336 3825] et al proposed the method of dynamic adjustment of the initial field. These methods all obtained good results in experiments.

Along with the use of meteorological satellites, one problem that needs to be solved urgently is how to utilize irregular (not fixed in time nor at a fixed locality) data. Our nation has already begun to study this problem and Huang Ronghui [7806 2837 6540], Li Chongyin, Yuan Chongguang et al conducted preliminary experiments.

5. Objective Analysis and Meteorological Systems Engineering

To enable the method of numerical forecasting to be used in daily operations, the first problems to be solved are automatic processing of meteorological data, input of data into the computer for weather map

analysis and for numerical forecasting, and output of the results, all of which should be automated. General objective analysis should include these three parts.

Research work in objective analysis in our nation is mostly directed towards the establishment of our nation's numerical forecasting operations. The objective analysis plan of the Shanghai Meteorological Observatory has been used in operations. The plan uses a polynomial of inserted values as the first approximation and then the results are gradually revised. Ji Liren and Liu Kewu [0491 0344 2976] of the Atmospheric Physics Institute cooperated with the Central Meteorological Bureau and designed a method of automatic processing of meteorological data via the telegraph and designed objective analysis by inserted values. They have completed many actual case experiments. In addition, Beijing University and Nanjing University have also conducted such studies.

The work of Ma Jipu and Jin Hanliang [6855 3352 5328] et al also achieved relatively good results in objective analysis of typhoon flow fields. Reference (203) patterned after the method of finite elements proposed a new course of thought. Ma Shufen [7456 3219 5358] tried Fourier expansion, repeated substitution and supplemental method to objectively analyze low latitude regions.

It should be pointed out that numerical forecasting operations are very huge and very complex automated engineering systems. Gu Zhenchao[2] had pointed out earlier that the relatively established aspects in weather forecasting and meteorological operations must be engineered. Therefore, a systems viewpoint must be used to recognize the developmental trends in numerical forecasting and to handle the work comprehensively and in an overall way so that the most logical and optimal results can be realized. Wang Zonghao et al began to study these types of problems since 1976. The theory of general systems analysis and the theory of composition and decomposition of large systems were applied and all important links that have been studied and those that have not been considered were studied, for example, transmission of compressed information signals, theoretical models of engineered numerical forecasting, combination and optimization of models, reading of weather maps and man-machine combinations.

Objective analysis and meteorological systems engineering are the most practical topics but our nation is relatively weak in these respects, thus research must be strengthened in the future.

6. Long Range Numerical Forecasting Experiments

Gu Zhenchao and Zhu Baozhen et al had proposed long range numerical forecasting in view of our nation's actual need as early as the late 1950's, and they had made corresponding arrangements and experiments. But because of the limiting conditions of the time, overall experiments were not possible. Since the 1970's, our nation has once again directed attention to this problem.

The numerical forecasting method presently in operation cannot be used for long range numerical forecasting because this method performs daily weather forecasts and predicts trends by step-by-step extrapolation as time progresses. The error in forecasting the weather half a month ahead is equivalent to climatic deviations. Therefore, such forecasts are meaningless to long range forecasts. A correct road towards long range numerical forecasting is to consider historical material. The key to success or failure is whether dynamics and statistics can be joined together well. Cao Hongxing [2580 7703 5281] has discussed this. Another correct road is to single out the long range evolutionary process and consider other factors as parameters exerting feedback effects. Therefore, the key to success or failure is whether the leading equation controlling long range processes is appropriate and whether the parametrization conforms to actuality. These two methods have both been studied in our nation. Experiments on the former include the work discussed in reference (119), which has achieved a definite result. Work concerned with the latter includes references (59), (72), (73), (208-210), and some results in experimental forecasting have been achieved. In these methods, ordinary synoptic systems (long waves) are filtered out as noise. The effects of non-adiabatic factors and the effects of clouds and radiation are subjected to parametric treatment, and consideration is given to the mutual effects between weather systems over land and weather systems over the sea. Experimental work is still in progress.

Comrades Wang Zonghao, Luo Maixia, Liang Youlin [2733 1635 2651] and many other comrades have written pieces for this article, have provided a lot of material and have helped the authors tremendously. We sincerely thank them.

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CHINA JET AIRCRAFT DEVELOPMENT DESCRIBED

Beijing HANGKONG ZHISHI [AERONAUTICAL KNOWLEDGE] in Chinese No 10, Oct 79 pp 4-5

[Article by Shi Qiushi [0670 3061 1395]: "New China's First Jet Aircraft"]

> [Text] The editors frequently receive letters from readers asking for more introductory articles on domestically produced airplanes and other aircraft. We have produced some introductory material, but not enough. In commemoration of the country's 30th anniversary, the September issue of this magazine described the first airplane produced in this country, and we plan to continue with an introduction to other Chinese-produced aircraft so that our readers will understand the progress our country has made in aviation during the last 30 years.

On 8 September 1956, New China News Agency and RENMIN RIBAO announced that this country had experimentally developed a new model jet aircraft. When the news came out, the people of the entire country hastened to spread it, and warmly welcomed this great achievement of New China's aviation industry, which also produced a shock in world aviation circles. This new jet aircraft was later formally designated the F-5.

New China's aviation industry was born a 'd the flames of the war against the United States and in support of Korea. From its official inception in April 1951 until 1953 it was primarily responsible for aircraft maintenance and the production of spare parts for front-line fighters. In 1954, it produced our country's first piston-engined elementary trainer, the Yak-18, which signaled that our country had begun to grasp aircraft production technology and had put an end to its history of inability to develop aircraft. New China's young aviation industry went forward from victory and advanced toward the jet airplane technology that was just developing at that time.

The F-5 fighter was modeled after the MiG-17, a product of the Mikoyan design bureau in the Soviet Union. This was a high subsonic speed fighter

interceptor with small volume, light weight and low-altitude maneuverability. The main capabilities and structural data are:

Top speed:	1,140 km/hr
Service ceiling:	16,000 meters
Maximum range:	1,570 km
Length:	11.25 meters
Wingspan:	10.53 meters
Net weight:	4,008 kg

Weight with full load of fuel, ammunition and outboard auxiliary fuel tanks: 5,334 kg.

Design: single-seat cockpit, centrally mounted single swept wings, all-metal construction. Stabilizers higher than wing. The main transverse structural members of the fuselage include 30 frame pieces and one diagonal frame piece. The main longitudinal structural members are a large beam, girders and stringers, fastened to the skin. The wings are swept back at a 45-degree angle and their relative thickness in the direction of airflow is 8.8 percent (average value), with a girder-and-frame construction. The vertical tail section is divided into upper and lower parts, with the lower part fixed to the rear of the fuselage and connected to the main beam, while the upper part is detachable. The airplane has 3-point landing gear with single wheels. The rudder and elevators are rigidly controlled, while the ailerons are servocontrolled. The airplane has one H-37 30-shot machine cannon and two HP-23 80-shot machine cannons.

The aircraft (excluding on-board instruments) consists of 253,550 parts of 14,719 different types.

Power plant: equipped with a Chinese-produced model 5 turbojet engine which is a modification of the Soviet Weika-A [4850 0595], which uses an afterburner to produce auxiliary burning and increase thrust. The thrust is 2,300 kg, and the afterburner thrust is 3,380 kg. The engine consists of a compressor, combustion chamber, turbine and afterburner and has 1,721 parts.

The F-5 and its engine were relatively advanced for their time and were relatively complex in structure; the work required for production preparation and trial production was rather extensive. For China's young aviation industry, the development and production of this aircraft was an extremely demanding task.

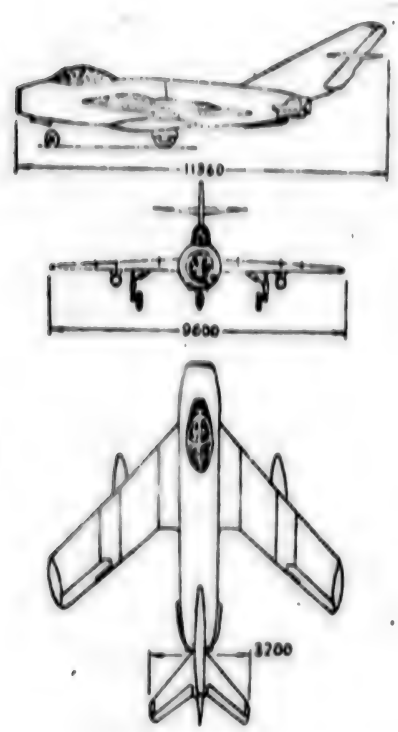
With the personal concern of the Party Central Committee, Chairman Mao and Premier Zhou, and with the energetic support of the people of the entire country, the broad mass of staff and workers in the aviation industry set out to confront the difficulties and boldly scaled the heights; and all the plants involved took on the tasks of developing the new aircraft products. The Shenyang Aircraft Plant, which was in charge of producing the

fuselage, had a general mobilization at all levels and embarked on intense development work with all its strength. Between February and September 1955 it victoriously completed all preparatory work for development of the airplane, using about 3,500 thousand workhours, equivalent to more than 1,600 man-years for technical personnel. Between September 1955 and February 1956, they completed the parts production assignment. Between February and August 1956 they were engaged in assembly and test flights. On 15 May the fore and aft parts of the fuselage and the wings were riveted together. In the last third of May they began initial assembly, then proceeded to intensive final assembly and test flights. During this period the aircraft industry successfully carried out the development work on the F-5, mounting a shock assault and gaining a complete victory. In May 1956, the engine plant successfully completed trial development of the No 5 turbojet engine. The aircraft was equipped with 34 instruments and 41 accessories, 67 electrical devices and auxiliary fittings such as wheel hubs, all of which were successfully developed by the relevant plants.

In July and August of 1956, the development work entered an intense experimental and test-flight stage. In the experiments, 38 components passed tests in 129 stress situations; the flight tests included 19 takeoffs and landings and 9 hours 49 minutes of flying time, and were completed on 2 August. After state acceptance testing, the conclusion was that the F-5 had passed, and it was formally accepted for series production.

China's workers and scientific and technical personnel had for the first time used their own hands to develop China's first modern fighter plane, and they made a reality of the Chinese people's hopes of many years. This was a great achievement in the reconstruction of our country's aviation industry which signaled that our country had advanced from the stage of aircraft repair and production of relatively simple trainers to a stage in which it could build its own new jet fighter. When people looked up to gaze at their own fighter plane soaring aloft on its wings and dominating the homeland's extensive airspace, they could not help but think back to the difficult times of the war of resistance against Japan and the war of liberation, when the Japanese imperialists' planes and the foreign aircraft used by the Chiang Kai-shek revolutionary clique engaged in frenzied bombing, and they remembered how many cities and towns had been quickly destroyed and how many innocent people had fallen to lie in their own blood. At that time, how they hoped that someday the Chinese people would have their own fighters! This wish had finally come true. When they compared the past with the present, how could they fail to be delighted?

In the 5 brief years between April 1951 and August 1956, New China's aviation industry had been able to draw upon a foreign technical base, and in a year and a half they had at one stroke successfully developed a new jet aircraft, something which would have been completely impossible in Old China and which was rapid even in the worldwide development of aviation.



Three views of the aircraft (dimensions are those of altered version).

8480
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APPLIED SCIENCES

REVISION OF CEMENT STANDARDS DETAILED

Beijing GUISUANYUAN XUEBAO [JOURNAL OF SILICATES] in Chinese Vol 7 No 4, Nov 79 pp 284-303

[Article by Huang Daneng [7806 1129 5174], Wang Youyun [3769 1635 0061], Wang Wenyi [3769 2429 5030], Tong Sanduo [4547 0005 1122], Shi Juanying [2457 1227 5391], Zhang Datong [1728 1129 0681], and Fang Derui [2455 1795 3843] of the Buildings Materials Research Institute: "Discussion of Some Problems in the Revision of Cement Standards in China"*]

[Text] Abstract

The newly revised standards for cements commonly used in our country--portland cement, ordinary portland cement, portland blast furnace slag cement, portland pozzolan cement and portland fly-ash cement--will be officially adopted on 1 January 1980. This paper treats the large amount of scientific research work carried out in the revision of these standards, and provides various technical data for the revision of the standards. It centers on a discussion of the four problems of amounts of aggregate that may be blended with various kinds of cement, criteria for MgO in clinker, SO_3 content, methods for testing strength, and grading. In establishing standards for portland cement and portland fly-ash cement, criteria for the upper limit of MgO in clinker have been relaxed from 4.5 percent to 6.0 percent (when it is from 5 to 6 percent, it must be tested for specifications in an autoclave). Amount of SO_3 has been relaxed to 3.5 percent (with relaxation to 4.0 percent in slag cement). Strength testing method has been changed from the earth-dry mortar test to the plastic mortar test. The delineation of new cement grades and the experimental formulae for converting cement grades to concrete grades are given detailed exposition. The economic benefits deriving from this revision of cement standards have been given particular analysis in terms of the expansion of varieties, improvement of quality, use of resources, and engineering quality.

1. Foreword

Our national cement standards are currently facing a complete reform. The National Bureau of Standards has already published six national standards

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for testing portland cement, ordinary portland cement, portland slag cement, portland pozzolan cement, portland fly-ash cement, and standard sand. These will be put into full effect on 1 January 1980. This reform of standards aims principally at improving the quality of our country's cement products. It also seeks to bring about conservation in the use of cement, assure quality in engineering, and benefit the spread of new construction technology. From the standpoint of production, it can expand sources of raw materials, the overall use of industrial wastes and the development of production technology, and it takes into account as far as possible the international nature of standards. Thus, it must have a rather large effect on the production, use, scientific research, and designing for use of cement in our country. This is a matter of importance for our nation's cement industry and for the capital construction front, which requires broad dissemination.

Our national standards of quality for ordinary portland cement, slag cement, and portland pozzolan cement first came into effect in 1956. For the past 20 years and more, these standards have played a necessary role in assuring product quality. But as our national cement industry has developed and new construction projects and various new technologies have appeared, it has become increasingly apparent that they no longer satisfy the needs of development. The main problems are that the earth-dry mortar testing method for strength cannot accurately reflect results for use of the cement in concrete. When a rather large amount of aggregate is mixed in with the cement, the grade tests are on the high side. Varieties and grades are unable to satisfy the needs of the development of project construction. Restrictions on harmful ingredients such as MgO are overly severe, and they impede, to a certain extent, full use of resources and the construction of new plants. Various physical testing facilities are old and out of date; their operation is tedious; they waste labor and time; and their accuracy is not good. Everyone is aware that the existing standards have been formulated basically on the standards of the 1940's prevailing at that time in the Soviet Union, and that the Soviet Union has long since discarded them. They are, of course, a far cry from current international standards for cement. Therefore, the broad masses of units engaged in production, construction, design, and scientific research have for a long time strongly demanded their complete revision.

The research and formulation work for the new standards began in 1972. A total of 75 units from 24 provinces, municipalities, and regions were organized to participate in this work. The current revised draft regulations were presented only after more than 4 years of joint efforts in which more than 8,000 cement samples were tested, 17 scientific experiments on special subjects were completed, more than 150 summaries of special topics and technical reports were put out, and more than 10 fairly large discussion meetings on special topics were held to seek a broad variety of views from every quarter.

The principal content of the reform of standards is as follows:

(1) In addition to the former ordinary portland cement, slag cement, and portland pozzolan cements, which have been retained, portland cement (pure clinker cement) and portland fly-ash cement have been added.

(2) The blend of slag in slag cement, which had been 20 to 85 percent heretofore, has been revised to 20 to 70 percent, and it is permitted to use either a mixture of pozzolan or fly-ash to take the place of some of the slag. The amount substituted should not amount to more than one-third the total amount of material added or 15 percent of the total volume of water. The volume of fly-ash in fly-ash cement is between 20 and 40 percent. In both pozzolan cement and fly-ash cement, less than one-third the total volume of material blended in may be slag.

(3) The method for testing cement strength has been changed from the earth-dry method to the plastic-mortar method. The new grade of fineness for cement is expressed by the figures "25." Common cement and portland cement have a maximum grade of 625#; slag, pozzolan, and fly-ash cements have a maximum grade of 525#. This represents an increase by about 150 (earth dry) over the maximum grade number of the old grades.

(4) The former stipulation that the amount of MgO in clinker could not exceed 4.5 percent has been revised not to exceed 6.0 percent, but when it is between 5.0 and 6.0 percent, it must go through soundness testing in an autoclave to meet specifications. Cement to which an amount of slag in excess of 40 percent has been added, or cement to which an amount of pozzolan or fly-ash in excess of 30 percent has been added, need not be subjected to soundess testing in an autoclave when the MgO in the clinker is between 5 and 6 percent.

(5) The former standard for SO_3 content in cement has been changed from 3.0 percent to 3.5 percent. For slag cement it has been changed to not in excess of 4.0 percent.

(6) To the methods for testing fineness has been added the water sieve method in addition to the dry sieve method. Testing using a quantity of water for standard consistency has been replaced by the use of a needle consistometer used in combination with the volume of water method in a single gaging of consistency. In the plastic mortar method, the proportion of lime to sand is 1:2.5, with the proportion of water to lime determined by the type of cement. For portland cement, ordinary cement and slag cement, it is 0.44. For pozzolan cement and fly-ash cement, it is 0.46. A revolving double-blade mixing machine blends the cement paste [gelatinous hydrated material], and it is vibrated into a shape on a vibration table. Measurements of the test volume are 4 x 4 x 16 centimeters. The test volume is first poured back and forth between two containers and then compressed; the surface area measurements following compression are 4 x 6.24 centimeters.

(7) Sand from Pingtan in Fujian Province is the standard sand used. There are no set proportions, unit weight, and nonquartzose content for it. Ignition loss has been changed from the former less than 0.3 percent to less than 0.4 percent, and silt carrying capacity has been changed from less than 1.0 percent to 0.2 percent. Fineness is 0.25 to 0.65 millimeters.

This article will now focus on the four problems of volume of material added to different varieties of cement, MgO in clinker, SO_3 content, methods of testing strength, and determination of grades.

2. The Problem of Amount of Aggregate Added to Different Types of Cement

There is no unanimity among the various nations of the world as to the basic principles and specific methods for determining types of cement. Instead, there is a tendency to start with use requirements, using properties and range of use as the principal basis. That is to say that it is required that the same types possess identical properties and ranges of use. At the present time in our own country, for the three most commonly used cements, namely ordinary portland cement, slag cement and pozzolan cement, the mixing of different kinds of different amounts of materials is used as the basis for this determination. These three kinds of cement are divided into various grades on the basis of their 28-day compressive strength. Their 28-day compressive strength aside, whether their rate of advance in early strength, as well as their requirements for water, shrinkage, corrosion resistance, resistance to freezing, and their heat of hydration meet the above principles for determining varieties of cement is a problem on which thought was focused during this current revision of cement standards. The practical experiences of more than 20 years require study anew of the following several problems:

(1) Determining whether or not it is necessary to set up a separate category purely for a type of clinker cement on the basis of differences when no aggregate whatever is mixed in the cement and when less than 15 percent of active materials are mixed in.

(2) Whether it is reasonable to place the upper limit for a mixture of active ingredients in common portland cement at 15 percent, to place the upper and lower limits for slag at 20 and 85 percent in slag cement, and to place the upper and lower limits for pozzolan in pozzolan cement at 20 and 50 percent.

(3) What outstanding differences there are in the effect on cement properties of fly-ash and other volcanic ash types in pozzolanic blends of materials, deciding therefrom whether it is necessary to set up a separate variety of fly-ash cement.

(4) The effect on the properties of cement of the mixing of slag into pozzolan cement and pozzolanic materials into slag cement.

While solving the above problems, research was undertaken into the effect on cement properties of different varieties of aggregates and the effect of different amounts being mixed into the same variety of cement.

1. The Effect on Cement Properties of Different Varieties of Aggregates

The International Standards Organization (ISO)[1] has proposed the following definition for granular blast furnace slag: a granular substance obtained from the rapid cooling of melted substances possessing certain chemical properties that have derived from the melting of iron ore in a blast furnace. They have recommended definition of pozzolanic composites as natural substances (volcanic products or diatomaceous earths) or man-made substances (burnt clay or fly-ash), when mixed together with lime and water at normal atmospheric temperatures are capable of producing hydraulic chemical compounds.

These are two completely different types of aggregate materials. Analyzed in terms of their mineral content, granular blast furnace slag possesses weak calcium silicate and aluminum silicate, minerals which themselves have weak hydraulicity and weak potential hydraulicity. Quenched in water and in the presence of lime or gypsum while in a vitreous state, their hydraulicity can be augmented. Pozzolanic composites are different. Usually they are minerals possessed of no hydraulicity in and of themselves. The active SiO_2 and Al_2O_3 in them forms into hydraulic chemical compounds only after being mixed with lime and water, and their absorption of lime is extremely slow at normal atmospheric temperatures. When, for example, clinker from the Jiangnan Cement Plant was mixed with 30 percent Xuanhua tuff, after 6 months the $Ca(OH)_2$ content of the cement stone had decreased by only 37 percent in comparison with the $Ca(OH)_2$ content of pure clinker after 6 months. Thus, the greater the volume of composite mixed in, the greater will be the effect on the strength of cement in its early stages when pozzolanic composite is added than when blast furnace slag is added. (See Figure 2 (2) and Figure (3) 2.) However, inasmuch as pozzolanic composites can absorb most of the calcium hydroxide that is separated out when the cement hydrates, pozzolan cement is superior to blast furnace slag cement in applications where resistance to fresh water or corrosion by sulfates is needed. Naturally, it is even more superior to pure clinker cement.

Further analysis in terms of physical structure, when the molten slag is quenched in water, since the volume of internal heat cannot keep up with the dissipation of heat and consequently cannot keep up with crystal formation, a vitreous mass of amorphous shape is maintained. Most pozzolan aggregate appears, therefore, as a very porous, formless substance with an extremely large internal surface area (Table 1). The effect of this structural difference on the property of cement appears, first of all, in water requirements. As the amount of pozzolanic aggregate mix increases, a rapid increase in volume of water is required to make a pozzolan cement

Table 1. Relative Internal Surface Areas and Dry Shrinking Properties of Different Pozzolanic Composites

Composite	Relative Internal Surface Area (meters^2/gram)	40 percent mix by volume. Relative dry shrinking values after 6 months*
Huadian diatomaceous earth	135	367
Xuanhua tuff	84	165
Fushun red shale	10	147
Shanghai fly ash	5	77

* When cement to which no aggregate has been added has a value of 100.

of standard consistency, while virtually no change occurs with blast furnace slag cement. (Figure 2 (1) and Figure 3 (1).) The increased amounts of water required cause an increase in dry shrinkage and a decline in resistance to freezing.

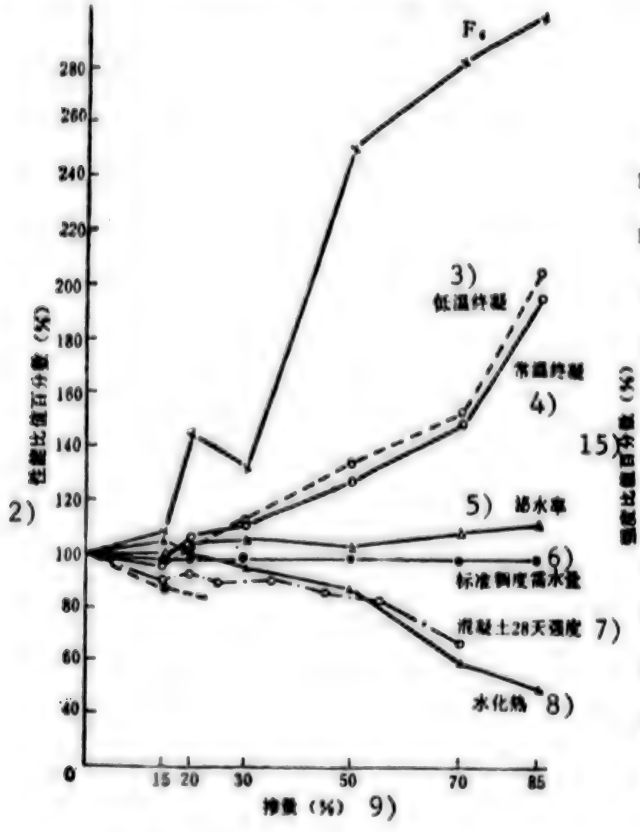
The types of pollozanic aggregates are numerous, however, and their causes of formation diverse. Among them, those with fly-ash properties are particularly outstanding. In terms of mineral composition, fly-ash contains a specific amount of α-quartz, mullite, β-C_2S and vitreous bodies. Some of these are themselves active substances, but more remarkable is the physical structure of fly-ash. Looked at under an electronic microscope, it is seen to consist principally of ball-shaped pellets of silicon, aluminum, and vitreous bodies (Figure 1 (1) and 1 (2) [not given] and 3.) It is this structure that gives rise to their lubricity and slushing; as revealed in its relative internal surface area, it is also far less than other fly-ash type substances (Table 1). These characteristics of fly-ash make it superior to other pollozanic concretes in terms of their requirements for water, their dry shrinking, and their resistance to cracking.

2. Effects of Different Quantities of Aggregates in the Properties of Cement

For more than 10 years large numbers of experiments have been conducted on the effect on cement properties of the mixing of blast furnace slag from 15 different steel mills and 7 different pozzolanic aggregates including red shale, tuff, gangue, pozzolana, burnt clay, fly-ash, and diatomaceous earths. Experiments consisted of standard consistency water requirements, final setting times at ordinary atmospheric temperatures at 5-10°C, corrosion resistance (F_6), weeping rate, hydration heat, and earth-dry and

plastic mortar strength tests at different ages. Inasmuch as characteristic differences were not great in the results of the experiments with these different kinds of aggregates, as well as for the sake of convenience in overall analysis, the data were separately averaged according to different amounts mixed in. Then, a value of 100 was assigned cement to which none of these aggregates had been added, and separate relative percentages were calculated for the amount of each of the aggregates mixed in to show the extent of change in properties.

Figures 2 (1) and 2(2) show the effect of a mixture of various amounts of slag on various properties and on strength. Figures 3(1) and 3(2) show the effects of pozzolana aggregate.



1) 图 2(1) 矿渣掺量对性能影响

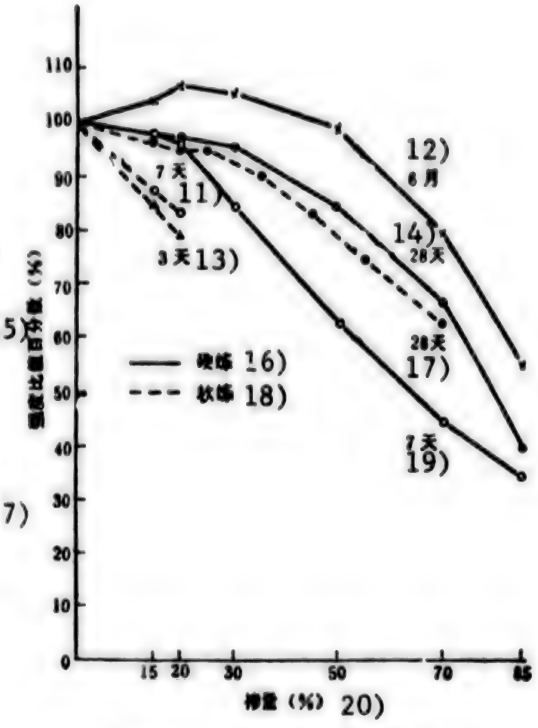


图 2(2) 矿渣掺量对强度影响 1)

Key:
1. Figure 2(1) effect of slag quantities on properties
2. Properties percentage value (percent)
3. Low temperature final setting
4. Normal atmospheric temperatures final setting
5. Weeping rate
6. Standard consistency water requirements
7. Concrete strength after 28 days
8. Heat of hydration
9. Quantity mixed (percent) [key continued]

10. Figure 2(2) Effects of slag quantities on strength
11. 7 days
12. 3 days
14. 28 days
15. Strength percentage value (percent)
16. Earth-dry testing
17. 28 days
18. Plastic mortar testing
19. 7 days
20. Quantity mixed (percent)

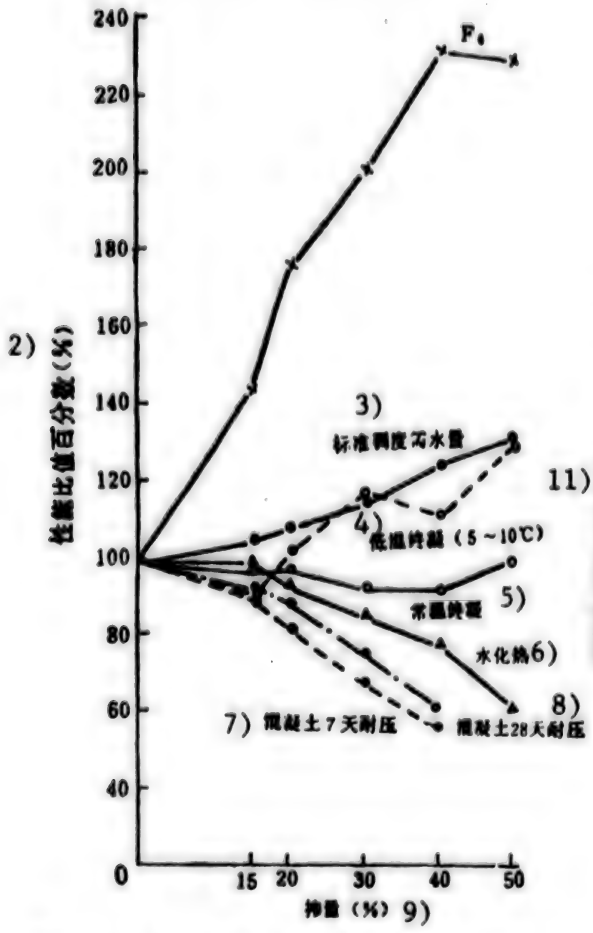


图 3(1) 火山灰质混合材料掺量对性能影响 1)

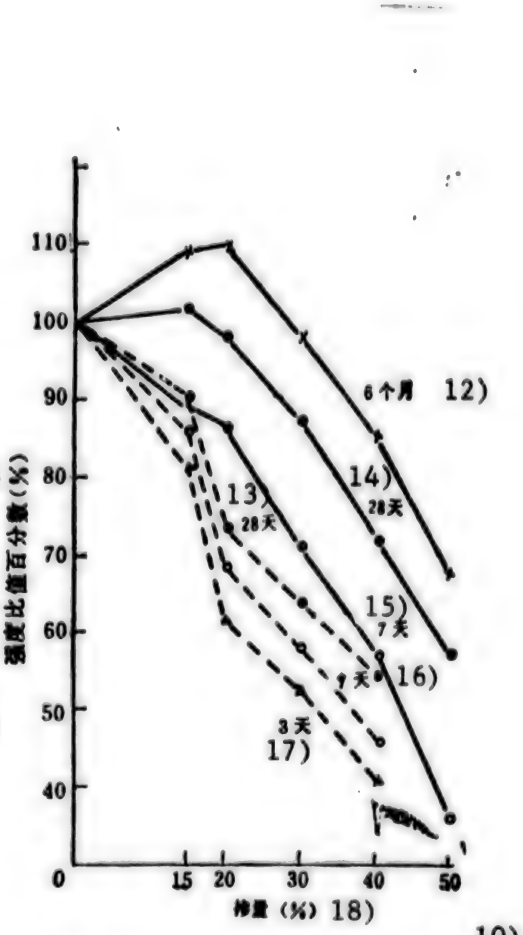
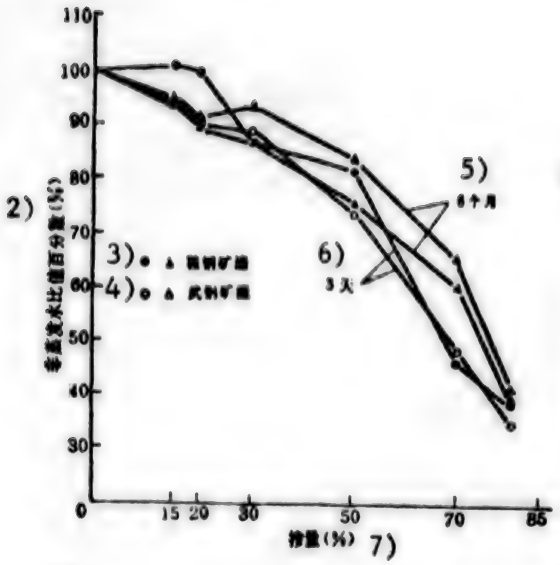


图 3(2) 火山灰质混合材料掺量对强度影响
——硬练 - - -软练

Key: [Figures 3(1), 3(2)]

1. Figure 3 (1) Effects on properties of amounts of pozzolan
2. Properties percentage value (percent)
3. Standard consistency water requirements
4. Low temperature final setting (5-10°C.)
5. Normal atmospheric temperature final setting
6. Heat of hydration
7. Pressure resistance of concrete after 7 days
8. Pressure resistance of concrete after 28 days
9. Quantity mixed (percent)
10. Figure 3 (2) Effects on strength of amounts of pozzolan
    (----plastic mortar method. _____earth-dry method)
11. Strength percentage value (percent)
12. 6 months
13. 28 days
14. 28 days
15. 7 days
16. 7 days
17. 3 days
18. Quantity mixed (percent)



1)

图 4(1) 水泥石中非蒸发水含量与矿渣掺量的关系

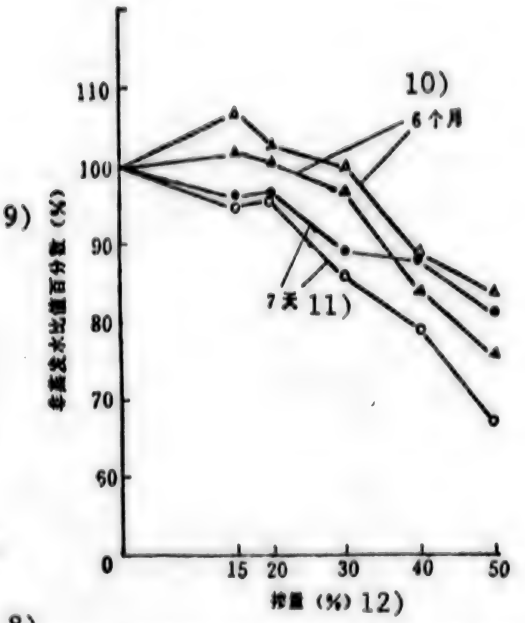


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图 4(2) 水泥石中非蒸发水含量与火山灰质混合材掺量的关系

13)●▲ 宣化凝灰岩 ○△ 上海粉煤灰14)

Key:

1. Figure 4(1) Relationship between water content without autoclaving and blast furnace slags mixture in cement rock
2. Percentage of water generated without autoclaving
3. Anshan Steel Mill blast furnace slag
4. Wuhan Steel Mill blast furnace slag
5. 6 months
6. 3 days
7. Quantity mixed (percent)
8. Figure 4(2) Relationship between water content without autoclaving and pozzolan mixture in cement rock
9. Percentage of water generated without autoclaving
10. 6 months
11. 7 days
12. Quantity mixed (percent)
13. Xuanhua tuff
14. Shanghai fly-ash

These figures show:

1) Standard Consistency Water Requirement: No substantial effect from the addition of blast furnace slag. The more pozzolana added, the greater the requirement. Rapid increase, particularly when amount added was in excess of 20 percent.

2) Final setting time: when amount of blast furnace slag exceeded 20 percent, time began to lengthen; above 30 percent noticeable lengthening of time occurred; and above 70 percent, the effects were even greater. Little difference between 5-10°C temperatures and normal atmospheric temperatures, but more noticeable at low temperatures. No clear effects for pozzolana on final setting at normal temperatures. At 5-10°C temperatures, final setting was lengthened when the amount of material exceeded 20 percent.

3) Corrosion coefficient (F_6): Began to increase when amount of blast furnace slag added exceeded 15 percent, with rapid increase above 30 percent, demonstrating a clear improvement in corrosiveness. Clear rise indicated with increase in amount of pozzolana seeming to peak at 40 percent.

4) Heat of hydration: No apparent change when volume of slag added was below 20 percent. Began to decline above 20 percent, and greater decline after 50 percent. Decline began to occur when amount of pozzolana exceeded 15 percent, after which decline was almost in a straight line.

5) Strength: As the amount of slag increased, strength declined no matter whether tested by the plastic mortar method or in concrete early stage. Plastic mortar testing and concrete testing rate of decline were greater. Rate of decline for 28-day testing was smaller on average, and did not become prominent until volume added exceeded 30 percent. A decline in strength began to show in 6-month earth-drying testing when volume added exceeded 50 percent; when 70 percent was added, the decline was in a straight line. Specifications for pozzolan portland cement and for blast furnace slag portland cement are the same, but rate of decline in strength was greater during the early stage for the pozzolan, and at 15 percent a very noticeable decline occurred.

In addition to the experiments on physical properties noted above, by way of further explanation of the problem, determination was also made of the water content generated without autoclaving from a quantity of hydrates derived from cement rock as shown in Figure 4(1) and 4(2). Characteristics and changes in strength were similar. Figure 5(3) shows the test section when a low pressure mercury orifice measuring device was used on a 1:3.5 [gelatinous hydrated material] test substance. It may be seen that as the amount of blast furnace slag increased, the aperture, and particularly the large aperture, showed a striking increase when the amount exceeded 50 percent. This shows that when the mixture of slag exceeds 50 percent, impermeability and resistance to freezing are seriously affected.

3. Views on Revision of Standards

To summarize the above experiments and analyses, the following revised views are offered on the delineation of types for existing standards and the quantity of aggregate mixed in:

1) A comparison of portland cement to which no aggregate of any kind has been added with a portland cement in which 15 percent aggregate has been added shows that the rate of strengthening during the early stage is clearly quite high, that the dry shrinking and resistance to freezing are quite good as well, but that the hydration heat is quite high, and the tolerance of sulfate corrosion quite poor. This shows that this cement fits the principal for delineating types given in the foregoing, and thus it must be differentiated from the present ordinary portland cement to form a category of its own.

2) Though fly-ash belongs to the category of pozzolana aggregates, it still exhibits quite large differences from other pozzolana both in terms of mineral composition and in analysis of physical structure; moreover, fly-ash cement exhibits rather slight properties of water requirement and dry shrinking, which makes it very workable in concrete; therefore, a separate category must be set up for it.

3) Whether it is slag or pozzolana admixture, when the amount of material to be mixed in is 15-20 percent, there is a fairly clear line of demarcation. For this reason, in order to distinguish most of the characteristics of ordinary cement, slag, and pozzolan cement, it is reasonable to maintain the 15 percent or less for ordinary cement and over 20 percent for slag or pozzolan cement, as specified in the original standards.

4) Once the quantity of slag added exceeds 70 percent, the strength of the cement declines drastically and the final setting becomes strikingly slow. This is a remarkable difference from the properties of slag cement in which the amount of slag is slight. Consequently, it is suggested that the mix of blast furnace slag in slag portland cement be lowered from 85 percent to 70 percent. The quantity of pozzolana in pozzolan cement can remain unchanged at its present limit.

5) Analysis of the effect on portland cement of blast furnace slag and pozzolana aggregate shows the two have different effects, but aside from water requirements, other effects amount to differences in degree, and the differences are not very noticeable. Therefore, a small amount of pozzolana aggregate in blast furnace slag portland cement or a small amount of blast furnace slag in pozzolan cement is entirely permissible, provided the amounts are kept within bounds and the inherent properties of the original type are maintained.

3. The Problem of Magnesia Norms in Clinker

Ever since it was discovered during the 1890's in certain bridges in France and in the municipal building in Kassel, Germany, that concrete made from cement with an MgO content in excess of 15 percent swelled and was destroyed, everyone has given great attention to the MgO content of cement. In order to prevent disastrous expansion of concrete projects

from magnesia, every country's standards limit the MgO content of cement. A look at currently prescribed norms in various countries shows that a large majority of them place the limit at no more than 5.0 percent, with some countries setting lower limits, and a small minority prescribing less than 6.0 percent. Heretofore our country's standards have been set at not more than 4.5 percent in clinker; however, this severe limitation on MgO content inevitably reduced use of limestone sources with high MgO content; consequently in recent years some countries have launched research into the manufacture of portland cement from limestone high in MgO.(2-4) Their research, however, has been in the category of types high in MgO, generally in excess of 10 percent. Though our country's limestone resources are abundant, considering that small cement plants are scattered all over the country, better use of limestone with high MgO content is a very real problem.

The problem of limits of MgO in portland cement clinker began to be researched long ago. As of the present time, the following has been learned: The total amount of MgO in cement clinker cannot precisely reflect its long-term stability. Because the form in which MgO exists in clinker differs greatly depending on the technology used for producing the clinker, it can exist both in the limestone or it can form into different size crystals of free crystalline periclase. The MgO that exists in various ores for clinker or the MgO that exists in glass is not harmful. The MgO that does the most harm by expanding is the free form crystalline periclase and the coarser the crystals, the more harmful the expansion. Therefore, it is believed that if certain measures can be taken in the production technology, to reduce the number of periclase crystals formed, particularly the large granular crystals, it will be possible even while raising the permissible MgO content to assure that the clinker's autoclave stability meets specifications.

1. The Effects of the MgO Content in Clinker on the Long-Term Strength and Engineering Durability of Cement

Clinker produced by the Benxi Cement Plant with an MgO content of 5.1 percent, 6.2 percent, 7.2 percent, and 7.5 percent and clinker from the Jiangnan Cement Plant with a 1.0 percent MgO content were separately milled into cement to which no aggregate was added and to cement in which blast furnace slag was mixed for comparative experiments. The results prove that: few differences exist in hydration heat, resistance to corrosion from sulfates, impenetrability, and dry shrinkage, and the advance in long-term strength was close to the results from 80°C steam curing.[5] Meriting attention is that the strength after 10 years (see Table 2), and the tensile strength of the steam cured cement that continued to be cured in water for 10 years continued to grow (Table 3) regardless of the MgO content.

In order to clarify the effect on the long-term durability of projects when the MgO in clinker is relatively high, investigations were made of the caissons in the piers at Qinhuangdao, water towers, cisterns, and multistoried

Table 2. Effects on Long-Term Strength of Cement Paste [gelatinous hydrated material] of MgO

1) 水泥厂名	2) 熟料 MgO (%)	3) 抗压强度 (公斤/厘米²)					4) 抗拉强度 (公斤/厘米²)				
		5) 28天*	6) 6月	7) 1年	8) 3年	9) 10年	5) 28天*	6) 6月	7) 1年	8) 3年	9) 10年
江10厂	1.0	686/100	835/122	853/124	915/133	990/144	38.5/100	39.2/117	43.2/129	43.2/129	42.6/127
本11厂	5.1	738/100	873/118	911/123	962/130	1010/137	34.0/100	32.1/95	34.4/101	39.6/116	42.4/125
本11厂	6.2	699/100	831/119	885/126	955/136	1034/148	34.1/100	34.1/100	36.6/107	38.5/113	41.5/121
本11厂	7.2	683/100	811/119	840/123	893/131	996/146	33.3/100	35.5/107	35.8/108	38.0/117	43.7/131
本11厂	7.5	733/100	861/117	891/121	940/128	1031/141	33.8/100	34.5/102	36.6/108	37.2/110	42.1/124

12) * 各分母数值为以28天为100的比值

Key:
1. Name of cement plant
2. Clinker MgO (percent
3. Compressive strength (kilograms/centimeters^2)
4. Tensile strength (kilograms centimeters^2)
5. 28 days
6. 6 months
7. 1 year
8. 3 years
9. 10 years
10. Jiangnan
11. Benxi
12. The numerical value of each denominator is on a scale of 28 days being 100.

buildings at Benxi, the piers at Yantai, and sluice gates in Anhui in a total of 32 construction projects. In all of these projects the cement clinker used contained more than 5 percent MgO (generally 5-7 percent), and some of the cement came from vertical kilns. The structures had been in use between 10 and 24 years. The project environment included open air, inside buildings, in water, and underground. Some of the projects had been faced with mortar; some were large expanses of concrete, and some were subjected to shock or carried loads. All were representative in one way or another. The results of on-the-ground inspection including meticulous observation and inspection using a resiliometer showed the quality of all projects to be still quite good with no expansion or splitting being discovered. Figure 6(4) [not given] was a retaining wall in a mine at the Benxi Cement Plant. The face of the wall was inclined with the top measuring 60 centimeters in thickness and the bottom 200. It was 400 centimeters high and 80 meters long. It contained a volume of 400 cubic meters of concrete. Built in the fall of 1950, it has endured for 29 years. MgO content of the clinker used was between 5 and 6 percent. For a long period of time the project has been exposed to the open air, but the concrete has still not expanded or split. The resiliometer checked the grade of the concrete at 200-300#.

1) 表 3 MgO对水泥砂浆养后强度增长影响

2) 水泥厂名	3) 熟料 MgO (%)	4) 抗压强度(公斤/厘米²)			5) 抗拉强度(公斤/厘米²)			
		20°C养护28天6)	80°C蒸养4小时7)	蒸养后水中28天8)	20°养护28天9)	80°蒸养4小时10)	蒸养后水中28天11)	蒸养后水中10年12)
13) 江南	1.0	686/100	460/67	636/93	36.7/100	22.4/61	32.3/88	42.9/117
14) 本溪	5.1	738/100	503/68	638/87	37.8/100	30.8/80	30.6/78	40.4/104
15) 本溪	6.2	699/100	454/65	655/94	33.7/100	22.0/65	30.1/89	38.9/115
16) 本溪	7.2	683/100	424/62	647/95	37.2/100	22.1/60	32.5/88	37.2/100
17) 本溪	7.5	733/100	480/66	655/89	35.0/100	21.3/61	31.8/91	41.7/119

18) • 各分母数值为以20°C养护28天为100的比值

19) •• 蒸养后水中10年仅做抗拉试验

Key: Table 3. Effects of MgO on Increased Strength of Gelatinous Hydrated Material Following Steam Curing

2. Name of cement plant
3. Clinker MgO (percent)
4. Compressive strength (kilos per square cm)
5. Tensile strength (kilos per square cm)
6. Curing at 20°C for 28 days
7. Curing at 80°C for 4 hours
8. Immersed in water for 28 days following curing
9. Curing at 20° for 28 days
10. Curing at 80° for 4 hours
11. Immersed in water for 28 days following curing
12. Immersed in water for 10 years following curing
13. Jiangnan
14-17. Benxi
18. The numerical value of each denominator is on a scale of curing for 28 days at 20°C being 100
19. Only tensile experiments were conducted on cement immersed in water for 10 years following curing.

2. Relationship Between MgO Content and Autoclave Stability

Since the particular form of MgO in cement clinker stems from a series of different production conditions, the composition of burden, the roasting temperatures, and the speed of cooling, when clinker with identical MgO content is used in different plants under different technological conditions, frequently notable differences occur in autoclave stability as a result of the different number of periclase crystals formed and their different sizes. Additionally, the CaO content varies, and that can also affect the experimental results of autoclave stability. Figure 7(4) [not given] shows a photograph taken through a microscope of the different size of the crystals of periclase in clinker from different plants. In

Table 4, the relationship between the CaO content of clinker from certain plants and expansion in the autoclave is presented. From Figure 7 it can be seen that the periclase crystals from clinker produced in shaft kilns in cement plants in Jinan and Yantai are larger than those from clinker produced in roller kilns in cement plants in Benxi and Kunming. Periclase crystals in clinker from shaft kilns measuring more than 10 microns were quite numerous with some crystals measuring 20 microns. Periclase crystals in clinker from roller kilns, however, were usually smaller than 10 microns with many measuring between 3 and 5 microns. Table 4 shows that though the MgO content of clinker from different plants is similar, autoclave expansion is by no means the same but is related to the free CaO, the periclase content, and the size of crystals in the clinker.

If production technology is fairly consistent in similar plants, and if there is no substantial change in the composition of the burden, the size of the periclase crystals may be virtually the same. In these circumstances a homologous situation exists in the relationship between periclase content and the total volume of MgO.[6] Table 5 shows the relationship between total volume of MgO and periclase content at the Benxi Cement Plant. It may be seen that under the technological conditions existing in the Benxi Plant, MgO content has been relaxed to 6.0 percent but autoclave stability of the cement is up to standard.

Table 4. Relationship Between MgO Content of Clinker and Expansion Rate in Autoclave for Different Plants

Plant	MgO (percent)	Free CaO (percent)	Periclase (percent)	Average diameter of periclase pellets (microns)	Autoclave Expansion Rate (percent)
Xiaotun Plant	4.50	0.60	2.10	5.10	0.23
Intermediate experimental plant	4.50	1.83	3.12	5.27	2.54
Benxi Plant	5.11	0.25	2.80	4.60	0.22
Fushun Plant	5.25	0.63	--	--	0.46
Benxi Plant	6.25		3.30	4.80	0.30
Kunming Plant	6.08	0.39	--	--	

Experience and production practice have demonstrated that when blast furnace slag or pozzolanic materials are mixed into cement, they have a buffering action on the expansion of the periclase, in fact reducing the MgO content of the cement. For this reason, great improvement in stability also shows up in the autoclave. Experiments further show that when the quantity of blast furnace slag exceeds 40 percent or when the pozzolanic materials exceed 30 percent, even though MgO is at 5-6 percent, stability in the autoclave meets standards.

Table 5. Relationship Between MgO Content and Periclase Content in Clinker from Benxi Cement Plant

MgO (percent)	Free CaO (percent)	Periclase (percent)	Autoclave Expansion (percent)
5.11	0.25	2.80	0.22
6.25	minute	3.30	0.18
6.50	0.29	3.60	0.19
7.28	0.30	3.90	0.60
7.53	0.26	4.30	0.48

3. Revision of Periclase Norms for Clinker

Based on the above analysis, in the new standards periclase norms have been relaxed from 4.5 percent to 6.0 percent with the stipulation that when it exceeds 5 percent, autoclave tests must be run on specifications. In this way complete assurance can be given on cement quality. Additional stipulations have been placed on blast furnace slag cement, pozzolan cement and fly-ash cement. When the periclase content of clinker stands at 5 to 6 percent, if the volume of blast furnace slag added is greater than 40 percent or the volume of pozzolanic material greater than 30 percent, the cement may be considered to meet standards without autoclave testing.

After relaxation of standards for the periclase, quarries belonging to 7 large and medium cement plants and to 24 small cement plants whose use has been restricted for varying numbers of years because of periclase problems have been put to use with clear economic benefit.

4. The Problem of Sulfur Trioxide Content

Gypsum is added to cement to regulate the setting time. If, however, too much gypsum is added, expansion of the volume of the concrete may result thereby endangering the safety of the structure. Consequently, the cement standards of every country in the world have for a long time severely limited the maximum SO_3 allowed. Our country's standards stipulate that SO_3 may not exceed 3 percent in ordinary portland, blast furnace slag, and pozzolan portland cement.

More recently, scholars have done a large amount of research on the proper volume of gypsum to be mixed into cement. They believe that slight relaxation of the conservative SO_3 restrictions would not only do no damage to the quality of structures, but could, under most circumstances, increase early stage strength, reduce dry shrinking, and improve durability. During

the past 20 years or more, many production and consumer units in our country have put forward numerous views on this matter. For example, in the rather finely milled quick-hardening cement, an appropriate excess of SO_3 beyond 3.0 percent is beneficial. In order to increase early stage strength of concrete and improve its impermeability, some cement manufacturing plants increase the amount of gypsum in the cement used at their own plants. Some small cement plants use gypsum as a mineralizer or they use fuel with high sulfur content, which causes the SO_3 content of their cement to exceed 3.0 percent with no apparent problems. All this experience shows that the limitation on SO_3 content in the original standards should be considered anew.

1. The Function of Gypsum in Portland Cement

Unless gypsum is added to portland cement, when water is added the very rapid hydration of C_3A may result in an abnormally rapid setting. When the proper amount of gypsum has been added, the gypsum can quickly react with the C_3A to produce very fine ettringite that covers the surface of the C_3A granules making them hydrate more slowly and causing the concrete setting time to be normal. When the cement's relative surface area is increased, as soon as the water is added to the cement, an increase occurs in the amounts of C_3A hydrate reacted substances. For this reason, when the relative surface area of the cement is large, or when the C_3A content of the cement is high, quite a large amount of gypsum must be mixed into it to regulate the setting time. When cement contains fairly large amounts of potassium or sodium with their alkaline content, since they fuse rapidly with C_3A, a goodly amount of gypsum must be added. With blast furnace slag portland cement, rapid setting does not occur when no gypsum is added. When gypsum is added, because the Al_2O_3 in the slag can react with gypsum when a certain amount of $Ca(OH)_2$ is present, to produce ettringite, the concrete sets harder. Thus, as the volume of slag mixed into the cement is increased, the amount of gypsum required increases commensurately.

In addition to regulating the setting time of concrete, gypsum also affects the strength of the cement as well as other of its properties. Experience has shown[7] that the ettringite produced by the reaction of gypsum with C_3A plays a different role at different stages of the hydration process. The ettringite produced before the slurry has been put in the form plays a role principally in the formation of a framework and in filling in spaces to make a dense structure, and consequently they help improve early stage strength. Additionally, the SO_3 ions can enter the hydrated calcium silicide to congeal.[8] The gypsum and the C_4AF can react to form calcium ferrosulfite. These substances act to fill in spaces and make the structure dense, thereby increasing the strength of the concrete and improving its properties of dry shrinkage, resistance to cold, and resistance to corrosion. Only when the quantity of gypsum added exceeds proper amounts, or when the moisture content is too high, or a reaction continues with the aluminate in the hardened cement rock to produce an

excess amount of ettringite, can a condition develop in which the cement expands and the structure is destroyed. Some scholars[9-11] have pointed out that the optiumum amount of gypsum in cement should be the amount that can virtually be consumed within 24 hours after being mixed with water. An excess of gypsum can lead to continued production of ettringite, which will cause expansion and destruction of the already hardened structure.

/. Effects of SO_3 Content on Cement Properties

Four kinds of clinker with varying amounts of C_3A were selected and mixed with different amounts of gypsum to prepare pure clinker cement, ordinary portland cement to which 15 percent blast furnace slag was added, slag cement to which 40 percent blast furnace slag was added, pozzolan cement to which 30 percent shale was added, and fly-ash cement to which 30 percent fly-ash was added as test samples of cement. After milling, the relative surface areas were about 3,000 square centimeters per gram on which the effectives of SO_3 on various properties were tested.

1) Effects of SO_3 content on setting period

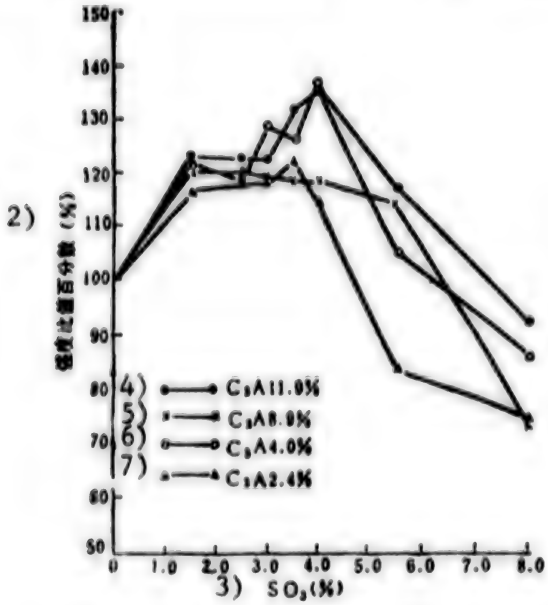
Table 6 shows the different reactions of SO_3 in setting times of cement containing different aggregates: on pure clinker cement, the early stage of setting was lengthened; on cements to which various aggregates had been added, the early stage setting and the late stage setting took place earlier. Increase of SO_3 content from 1.5 percent to 8.0 percent had no noticeable effect on either the early or late stage setting period.

Table 6. Effects of Sulfur Trioxide Content on Setting Times

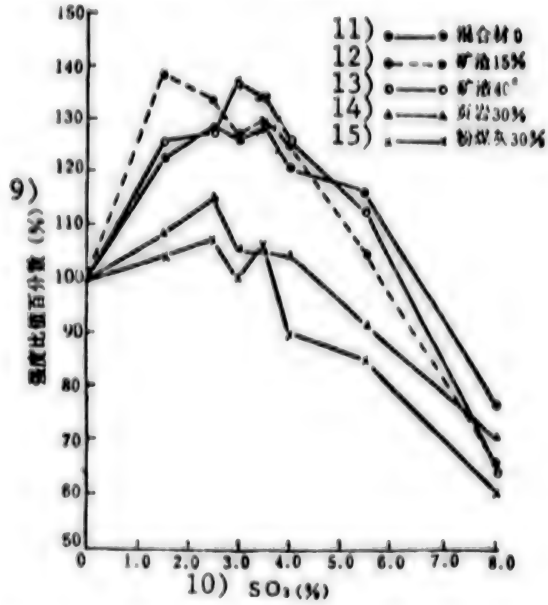
SO_3 (percent)	Aggregate (0 percent)		Slag (15 percent)		Slag (40 percent)		Shale (30 percent)		Fly-ash (30 percent)	
	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
0	0:10	4:04	3:31	8:06	7:46	11:40	12:16	25:17	5:01	8:52
1.5	1.40	3:41	1:46	3:49	3:03	4:54	4:17	5:32	2:49	5:02
3.0	1:51	4:18	2:07	3:58	2:51	4:27	4:00	5:33	2:04	4:56
4.0	2:03	4:25	1:59	3:44	3:19	5:25	3:52	5:29	3:27	5:09
8.0	1:57	3:57	1:58	4:03	3:26	5:24	2:47	5:54	2:43	5:17

2) Effects of SO_3 content on strength

Figure 8 shows that within proper limits, SO_3 is beneficial to the strength of pure clinker cement containing various amounts of C_3A, but, in general, when SO_3 is between 3 and 4 percent, a high point is reached. When the amount exceeds 4.0 percent, a noticeably dramatic decline occurs. The optimum content of SO_3 has a tendency to increase when C_3A increases. Figure 9 shows the effects on strength of cement in which various aggregates have been mixed. Characteristics are similar to those in Figure 8 with the strength peaking when the SO_3 is between 1.5 and 4.0 percent with a general decline when it exceeds 4.0 percent. Table 7 shows that though SO_3 exceeded 3.0 percent, when it reached 3.5 percent clinker with varying C_3A content showed continued increase in strength from the 28th day until a year afterward, with no shrinking.



1) 图 8 SO_3含量对不同C_3A熟料强度影响



8) 图 9 SO_3含量对掺不同混合材水泥强度影响

Key:

1. Effect of SO_3 on Strength of Clinker Containing Different Amounts of C_3A
2. Strength values (percent)
3. SO_3 (percent
4. C_3A 11.9 percent
5. C_3A 8.9 percent
6. C_3A 4.0 percent
7. C_3A 2.4 percent
8. Effect of SO_3 on Strength of Cement Containing Various Amounts of Aggregate
9. Strength values (percent)
10. SO_3 (percent)
11. Aggregate o
12. Blast furnace slag 15 percent
13. Blast furnace slag 40 percent
14. Shale 30 percent
15. Fly-ash 30 percent

Table 7. Rate of Strengthening for Clinker with Different C_3A Content when SO_3 is 3.5 Percent

C_3A (percent)	Strength in Percentages at Various Ages with 28 Days Being 100 Percent						
	1 day	3 days	7 days	28 days	3 months	6 months	1 year
11.9	51	63	87	100	107	111	114
8.9	30	49	79	100	107	111	116
4.0	32	47	78	100	113	122	119
2.4	16	47	61	100	134	161	166

3) Relationship of SO_3 content to swelling rate

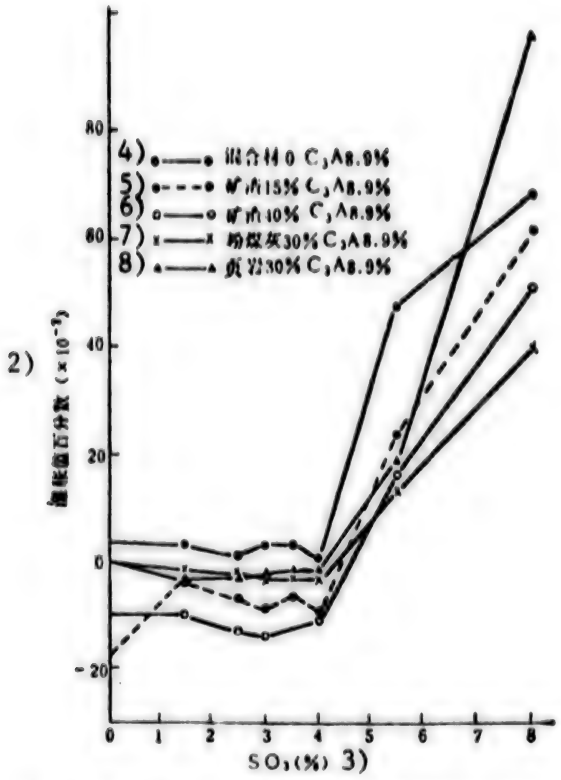
It may be seen clearly from Figures 10 and 11 that when the SO_3 content exceeds 4.0 percent, the swelling rate makes a noticeable rise for clinker with different C_3A content, or for cement to which different amounts of aggregate have been added. This shows that when the amount of gypsum added exceeds a certain figure, when the amount of water is adequate, the SO_3 reacting with the C_3A in the clinker continues to hydrate the ettringite produced, and leads to a fairly large swelling in the cement rock, whose spaces are already full, and the extent of swelling increases as the C_3A increases.

4) Relationship of SO_3 content to resistance to freezing

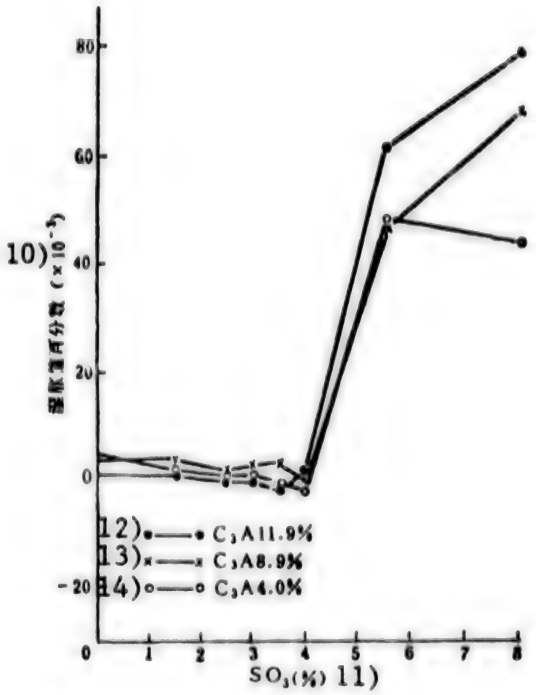
Figures 12 and 13 show that the SO_3 content has about the same effect on the resistance to freezing and on strength, namely, as the SO_3 increases, resistance to freezing increases. However, once the SO_3 reaches between 3 and 4 percent, a rapid decline occurs.

3. Some Views on the Revision of Permitted SO_3 Content

A look at standards in some foreign countries shows that some of them, such as Great Britain and the United States, link restrictions on SO_3 content to the C_3A content, which is to say that when the C_3A content exceeds 7 or 8 percent, restrictions on SO_3 are relaxed. The German Democratic Republic links SO_3 to relative surface area. When the relative surface area exceeds 4,000 square centimeters per gram, restrictions on SO_3 are relaxed. Many countries such as Japan and France have different regulations depending on the type of cement or the amount of aggregate in it. In general, when the amount of aggregate mixed in is



1) 图 10 SO_3含量对不同C_3A熟料湿胀性影响

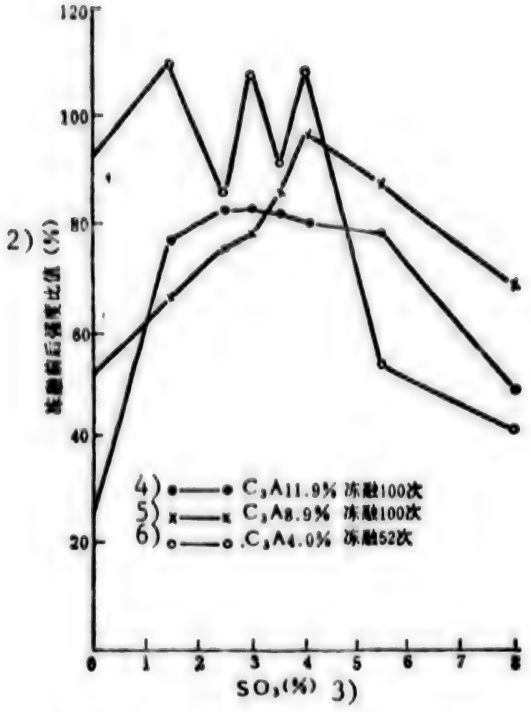


9)

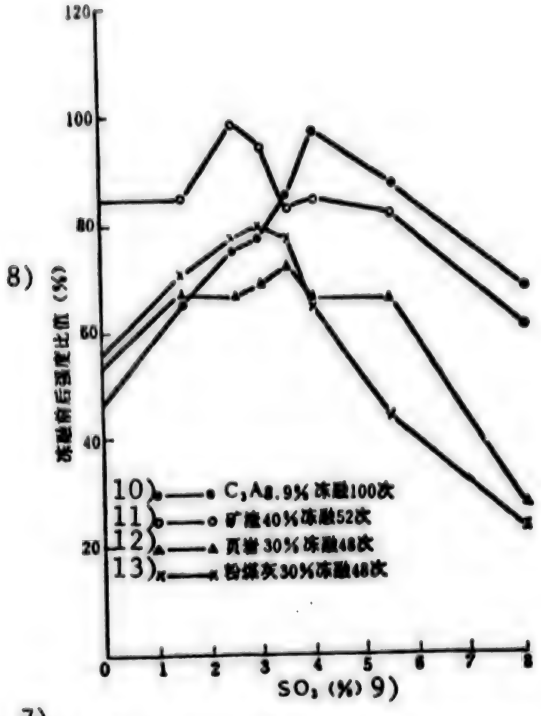
图 11 SO_3含量对掺不同混合材水泥湿胀性影响

Key:

1. Figure 10. Effects of SO_3 on Swelling of Clinker Containing Different Amounts of C_3A
2. Swelling value in percent (x 10^{-3})
3. SO_3 (percent)
4. Aggregate 0 C_3A 8.9 percent
5. Blast furnace slag 15 percent C_3A 8.9 percent
6. Blast furnace slag 40 percent C_3A 8.9 percent
7. Fly-ash 30 percent C_3A 8.9 percent
8. Shale 30 percent C_3A 8.9 percent
9. Figure 11. Effects on SO_3 on Swelling of Cement Containing Different Amounts of Aggregate
10. Swelling value in percent (x 10^{-3})
11. SO_3 (percent)
12. C_3A 11.9 percent
13. C_3A 8.9 percent
14. C_3A 4.0 percent



1) 图 12 SO_3含量对不同C_3A熟料抗冻性影响



7) 图 13 SO_3含量对掺不同混合材水泥抗冻性影响

Key:

1. Figure 12. Effects of SO_3 on Resistance to Freezing of Clinker Containing Different Amounts of C_3A
2. Strength values (percent) for alternate freezing and thawing
3. SO_3 (percent)
4. C_3A 11.9 percent with freezing and thawing 100 times
5. C_3A 8.9 percent with freezing and thawing 100 times
6. C_3A 4.0 percent with freezing and thawing 52 times
7. Figure 13. Effects of SO_3 on Resistance to Freezing of Cement Containing Different Amounts of Aggregate
8. Strength values (percent) for alternate freezing and thawing
9. SO_3 (percent)
10. C_3A 8.9 percent with freezing and thawing 100 times
11. Blast furnace slag 40 percent with freezing and thawing 50 times
12. Shale 30 percent with freezing and thawing 48 times
13. Fly-ash 30 percent with freezing and thawing 48 times

fairly substantial, the SO_3 restrictions are relaxed. Generally speaking, most countries limit SO_3 content to less than 3.5 to 4.0 percent.

From an analysis of the results of our experiments, we conclude that the former standards, which restricted the SO_3 content to 3 percent, were clearly of no help in getting the most benefit from the improvement in cement properties that gypsum can confer; therefore they would be appropriately relaxed. Furthermore, though a suitable SO_3 content is definitely linked to the C_3A content of clinker, inasmuch as a preponderant amount of the cement manufactured in our country has aggregate mixed into it, it is the relationship of the quantity of aggregate that is more important to the SO_3. The effect of blast furnace slag is particularly important. An analysis of experimental results shows that when the amount of blast furnace slag in the cement exceeds 20 percent, an appropriate relaxation of SO_3 restrictions is clearly called for inasmuch as gypsum promotes setting and hardening, and it particularly promotes early stage strength. The results of the experiments also show that in all cement, whenever the SO_3 exceeds 4.0 percent, a dramatic decline in all of the cement's properties takes place. Consequently, it is recommended that except for a relaxation of SO_3 content to 4.0 percent for blast furnace slag cement, a relaxation to 3.5 percent should be made for other portland cements, ordinary cement, pozzolan cement and fly-ash cement.

5. Problems in Testing Strength and Determining Grade

Two main factors determine the strength of concrete: the proportion of water to lime and the strength of the cement. But different methods for testing cement strength can show very different cement strengths on the same test specimen. This shows that different testing methods can give vastly different results about the objective activeness of cement and about the accuracy of predictions about the strength of concrete. This has required that we very carefully study methods for testing the strength of cement, and consider whether it is possible to accurately gage the strength of concrete from a specific proportion of cement, which is to ask whether methods for testing cement strength are the first important criteria.

Every batch of cement produced by a cement plant must have its strength regulated. Therefore, cement producers invariably demand simple and easy testing methods that are both quick and accurate. For more than 20 years, our country has steadfastly determined various grades for cement, which has required that producers be able to accurately test the strength of the cement. So when equipment is simple and easy to use, both time and labor are saved, and testing accuracy is another important criterion of whether testing methods for measuring strength are advanced.

1. Prevailing Strength Testing Methods Must Be Improved

On the basis of an inspection of whether the two above-stated test methods for gaging strength were advanced criteria, it appears that rather large improvements must be made in prevailing strength testing methods in our country.

In the existing method, a rather small volume of water is used (with the usual ratio of water to lime being below 0.35), with the resulting cement paste [gelatinous hydrated material] being quite dry, and a ramming machine is required to form it in the so-called earth-dry method. Though it has played an active role during the past 20 years or more in assuring cement quality, it is becoming increasingly apparent that this method has a serious shortcoming in that it cannot accurately reflect the activeness inherent in cement to which a fairly large amount of aggregates have been mixed. Using the formula for calculating water volume, the respective water addition K-constants for slag cement and ordinary cement are 1.80 and 2.60, and clearly the former uses too little water. Though pozzolan cement has a rather large requirement for water, the K-value is also only 2.40. Such unreasonable volumes of water used for mixing together with the use of ramming in molding makes the strength test results for slag cement and pozzolan cement clearly rather high in comparison with ordinary cement.

Therefore, if the same grades of slag cement and ordinary cement are formulated at the same ratios of water to lime to make concrete, the strength of the former will be lower by 10 percent or more than that of the latter. Such results are serious when the same grades of cement cannot produce the same grades of concrete. It must inevitably lead to the broad masses of cement consumers losing confidence in slag cement, and it will inevitably increase difficulties in controlling the quality of concrete. In circumstances under which there is no choice but to use slag cement, it must also inevitably result in incalculable waste of cement.

Still another serious problem with prevailing methods is the complexity of equipment, the unwieldiness of its operation, and its waste of labor and time without providing accurate results readily. For the medium and small cement plants and the on-site testing laboratories throughout our country, it is difficult to operate and difficult to master. It seriously harms control of accuracy in cement quality, and it does not help assure quality in building projects. Type "8" tensile testing is particularly difficult to control accurately, and for many years this has been considered to be a stumbling block in the accurate control of quality.

2. Strong Points of New Methods

After focusing on the shortcomings of existing methods, my institute, in cooperation with several dozen units, have conducted a great amount of experimental research on the following key links over a period of several years:

1) In the fixing of the lime-sand ratio and the water-lime ratio, the composition of the cement paste [gelatinous hydrated material] will have a good plasticity, and it should also be able to reflect accurately the activeness of the cement, which should be interrelated with the strength of the concrete. Strikingly, once the new method was used, whenever the slag cement and the ordinary cement were of the same grade, virtually the same grade of concrete could be produced.

2) For a standard sand with consistent granularity, existing sand sources at Pingtan in Fujian Province were used entirely; this sand made for a readily mixable cement paste [gelatinous hydrated material].

3) Measurements of volumes tested and shape requirements made handling easy; the forms were easy to build; and they showed the activeness of cement under varying stresses.

4) Mixing and forming. To get a smooth result in mixing, the equipment had to be uncomplicated and its operation easily mastered. Under the new method, forming up of the material required less than half the time and labor of the old method.

A comparison of our country's new method with the standard methods of some other countries (including the RILEMCEMBUREAU method of the International Standards Organization ISO/R679-68) is presented in Table 8. It may be seen that the methods used by each country are virtually the same with only minor differences, with the principal points in common being that they all use the plastic mortar method in which the ratio of water to lime is above 0.40; the volume of water used is fixed; and the ramming method has been abandoned in favor of mechanical or hand vibration to shape the material.

3. Strength Relationship Under Old and New System and New Grading of Cement

Our institute organized more than 20 cooperating units throughout the country to conduct comparative experiments on cement strength using both new and old methods on more than 2,000 representative cement samples. Next it used the least square method to prepare mathematical statistics to find the following experimental formulae for calculating strengths under the new and old methods for ordinary cement and for slag cement (including pozzolan cement):

Ordinary cement $$R^{\text{earth-dry}}_{28\ \text{pressure}} = 1.20 R^{\text{plastic mortar}}_{28\ \text{pressure}} - 17$$

Slag cement and pozzolan cement $$R^{\text{earth-dry}}_{28\ \text{pressure}} = 1.16 R^{\text{plastic mortar}}_{28\ \text{pressure}} + 50$$

Table 8. A Comparison of Strength Testing Methods in Our Country with Those of Other Countries

Country	Plastic Mortar or Earth-Dry Method	Cement Paste Composition			Measurements and Shape of Test Material		Shaping Method	
		Lime-Sand Ratio	Water-Lime Ratio	Grain Size of Standard Sand	Measurements and Shape	Method of Breaking Mold	Mixing	Shaping
China (GB177-77)	Plastic	1:2.5	0.44 Stable 0.46	0.25-0.65 Two grades of mixed sand	4x4x16 prism	Break resistance and 4x6.5 cm compression	Twin blade revolving mixer	Vibration table with drain. 3,000 vibrations per minute
International Standards Organization (ISO/ R627/68 R-C method)	Plastic	1:3.0	0.50 Stable	Coarse 1:00-2:00 Medium 0.50-1:00 Fine 0.08-0.50 blended sand	4x4x16 prism	Break resistance and 4x6.5 cm compression	Blade mixer	60 times per minute Extension-arm type shaker
United States (ASTM C109-73)	Plastic	1:2.75	0.485 Stable 0.460	0.15-1.18 blended sand	5.0 cube	only 5.0x5.0 cms compression	same as ISO	Hand tamping
United Kingdom* (BS12-71)	Plastic	1:3.0	0.40 Stable	0.60-0.85 uniform sand	7.07 cube	only 7.07x7.07 cms compression	Hand tamping	12,000 times per minute, vibration table
West Germany (DIN1164-72)	Plastic	1:3.0	0.50 Stable	Same as ISO	4x4x16 prism	only 4x.6.25 cms compression	Same as ISO	3,000 times per minute on vibration table
Japan (JISR 5201-77)	Plastic	1:2.0	0.65 Stable	0.105-0.297 uniform sand	4x4x16 prism	on 4x4 cms compression	Hand mix & machine mix	Hand tamper
France (NPF15-451-63)	Plastic	1:3.0	0.50 Stable	Same as ISO	4x4x16 prism	User units, unless required, use only 4x4 cms compression	Same as ISO	Same as ISO
USSR (GOST310-76)	Plastic	1:3.0	0.40 Stable or gage fluidity 105-110 cms	0.50-0.85 uniform sand	4x4x16 prism	Break resistance and 4x6.25 cms compression	Earth-dry roller mixing machine	3,000 times per minute on vibration table

*Concrete method and cement paste [gelatinous hydrated material] method are also used as part of British standards.

These two experimental formulae have been plotted on Figure 14. From this figure, it may be seen that the vertical distance for the ordinary cement and the slag or pozzolan cements is about 40 kilograms per square centimeter, and that the horizontal distance is about 50 kilograms per square centimeter. This shows that when the same earth-dry grading is used, the plastic mortar test strength for slag and pozzolan cement should be increased by about 40 kilograms per square centimeter to make it equal that of the ordinary cement. Alternatively, the earth dry strength has to be increased by about 50 kilograms per square centimeter to reach the same plastic mortar grade. This will greatly improve the quality of our country's slag cement and its pozzolan cement.

The new grading of cement is based on the above relationship between old and new grades.

Determination of new grades for cement should start with cement production realities as they exis[illegible] ar country, with a reduction of fluctuations in production insofar as possible. Grading of different types of cement should be consistent so as to help improve cement quality and its rational use.

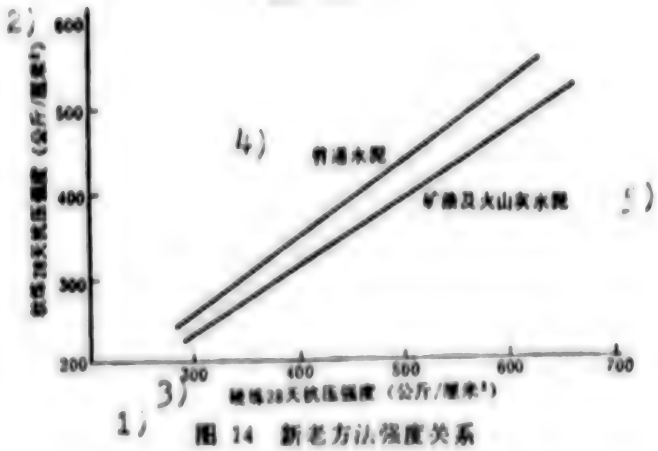


图 14 新老方法强度关系

Key:
1. Figure 14. Strength relationships under new and old methods
2. Plastic mortar method 28-day compressive strength (kilos per cm^2)
3. Earth dry method 28-day compressive strength (kilos per cm^2)
4. Ordinary cement
5. Slag and pozzolan cement

In the determination of new grades, three different plans were considered. These are shown in Table 9. The point common to all three plans is a difference of 100# between grades, which is roughly equivalent to the 120# of the earth-dry tests. This makes for convenience in production and use. In consideration of realities in small cement plants, the distance has been shortened to 50# for low grades. A comparison of the

1. 各種新標号区分方案

2. 水泥品种	3. 第一方案		4. 第二方案		5. 第三方案	
	6. 软练标号	7. 相当于旱练标号	8. 软练标号	9. 相当于旱练标号	10. 软练标号	11. 相当于旱练标号
12. 普通水泥	200	236	250	294	225	265
	250	294	300	352	275	323
	300	352	350	410	325	381
	400	468	450	526	425	497
	500	585	550	643	525	614
	600	701	650	759	625	730
13. 矿渣水泥	200	274	250	336	225	306
	250	336	300	398	275	367
	300	398	350	459	325	428
	400	520	450	580	425	550
	500	641	550	700	525	671

Key: Table 9. New Grading Plans
2. Type cement
3. Plan 1
4. Plan 2
5. Plan 3
6. Soft mortar grade
7. Equivalent to earth-dry grade
8. Soft-mortar grade
9. Equivalent to earth-dry grade
10. Soft-mortar grade
11. Equivalent to earth-dry grade

three plans shows that the grades for the first plan are all whole numbers, which is, of course, handy for users. But in consideration of reducing effects on production to the greatest extent possible, were the first plan to be used when current production volume of ordinary cement is a maximum of 500#, the earth-dry grade would have to be raised by 85# to make a plastic mortar grade of 500#, or else be reduced by 32 to make a plastic mortar grade of 400#. This would result in a situation of "the higher number won't do and the lower number won't suit." It would inevitably lead to chaos in production. The situation for the second plan is a little better; however 500# ordinary cement would still have to be raised by 26# to be the same as 450#. For most plants this would still be difficult of accomplishment. In the third plan, earth-dry 497# is equivalent to plastic mortar 325#, both of which are easy to manage with minimal effect on production. Therefore, though the third plan grades are not whole numbers, clearly they are more suitable by comparison with the others.

At the present time, most slag cement produced is in the earth-dry 400# grade. In the first and second plans, this is equal to plastic mortar 300#, but for the sake of consistency with ordinary cement, the third plan is used. When this is done, slag cement with an earth-dry 400# has to be raised 28# to make it a plastic mortar 325#, and 500# must be raised 50# to make a 425#. There are some difficulties. However,

when the aggregate in slag cement accounts for quite a bit of the volume, there is a wide margin for adjusting grade. Use of the third plan also helps upgrade the quality of slag cement, and this is appropriate over the long run.

In order to satisfy requirements of consumer units about highly graded cement, ordinary cement has been increased to 625#, equivalent to 730# in the earth-dry method. Slag cement has been increased to 525#, equivalent to 671# in the earth-dry method. These represent increases of 150# over the highest grades in the old standards. At the same time, since low grades of cement are still very much in demand, and out of concern for the actualities in some small cement plants, the lowest grade for ordinary cement was fixed at 225#, which is equivalent to earth-dry 266#. Slag cement was fixed at 225#, which is equivalent of earth-dry 306#. Grading of pozzolan cement and fly-ash cement is, therefore, consistent with that of slag cement.

Standards for the 3 and 7 day strengths of various types and grades of cement were based on the actual rate of strengthening of each variety of cement. Compressive strength and breaking strength norms at each age were set on the basis of the actual relationship of compressive strength and breaking strength. The previously prescribed earth-dry norms in the old standards are now for reference only.

The mineral composition of clinker, fineness, quantity of gypsum added, free lime content, and quantity of aggregate added have a different effect on the plastic mortar strength and the earth-dry strength, particularly on the rate of strengthening. Consequently, in putting the new standards to use, some technical difficulties are bound to be encountered. But, since the new standards are superior in so many ways, improvements in production technology in each plant to overcome these various difficulties, and the improvement in quality, will inevitably help the development of our country's cement industry.

4. Relationship Between New Cement Standards and Concrete Standards

Grading of cement has a goal other than delineating quality in terms of degrees of strength. Another function is accurate gaging of concrete grades on the basis of cement grades, thereby achieving an equitable use of cement and a reduction of cement waste. Therefore, once the new standards for cement were proposed, it was necessary to find their relationship to strength of concrete, both to be able to provide these to user units for their reference and, through a comparison with earth-dry test grades, to determine the superiority of the new grades.

Our institute, in cooperation with 14 cooperating units, conducted a series of plastic-mortar experiments, earth-dry experiments, and concrete strength experiments using 102 cement samples from 64 large,

medium, and small cement plants in our country. The water-lime ratios used for the concrete were 0.40, 0.55, and 0.70 with quantity of cement used as close as possible. The slump constant was held in the 2 - 6 centimeter range; test materials were all 10 centimeter cubic measure, and strength derived was multiplied by 0.90 to convert to 20 centimeters cube standard strength. Results of the experiments (n) were regressively analyzed in an electronic computer using the least square method as $R_{concrete}/R_{plastic\ mortar}/R_{earth\text{-}dry}$ being y, and the lime-water ratio being x to obtain a regressive straight line formula y = a + bx and the interrelated figure γ, after which the regressive straight line formula was written in the following experimental way:

$$R_{concrete} = {}^{AR}_{\substack{\text{plastic mortar} \\ \text{or} \\ \text{earth-dry}}} \left(\frac{\text{lime}}{\text{water}} - B \right)$$

By using this experimental formula, the difference between the actual test value for the concrete, $R^{actual}_{concrete}$, and the calculated value $R^{calculated}_{concrete}$ was calculated and an average deviation, $\overline{V}$, was derived to calculate the accuracy of concrete grades using a comparison of plastic mortar and earth-dry grades.

$$\overline{V}\ (\text{percent}) = \frac{\sum \left(\frac{R^{actual}_{concrete} - R^{calculated}_{concrete}}{R^{actual}_{concrete}} \right)}{n} \times 100$$

See Table 10 for the experimental formulae collected from various cooperating units throughout the country. It may be seen from this table that the relationship between the new cement standards and the strength of concrete is superior to the old standards as shown in the high relationship figure γ, and the lesser deviation, $\overline{V}$.

In order to compare plastic mortar and earth-dry strength tests for differences in how they reflect the strength of different types of cement, statistics for ordinary cement strength, slag cement strength and concrete strength have been separately provided (aging for only 28 days), and these experimental formulae have been displayed in Figures 15 and 16. These figures show that no matter whether crushed rock cement or pebble cement, with the same grade of cement as determined by earth-dry testing, ordinary cement makes cement of much higher strength with all water-lime proportions than does slag cement. Using the same grades as determined by plastic mortar testing, the strength of concrete made from both types of cement is extremely close. This clearly demonstrates that through the use of new grades from the plastic-mortar method, a substantial reversal can be made in the abnormal phenomenon of concrete made from slag cement being lower in strength than concrete made from ordinary cement of the same grade.

Table 10. Experimental Formulae Provided by Cooperating Units Throughout the Country

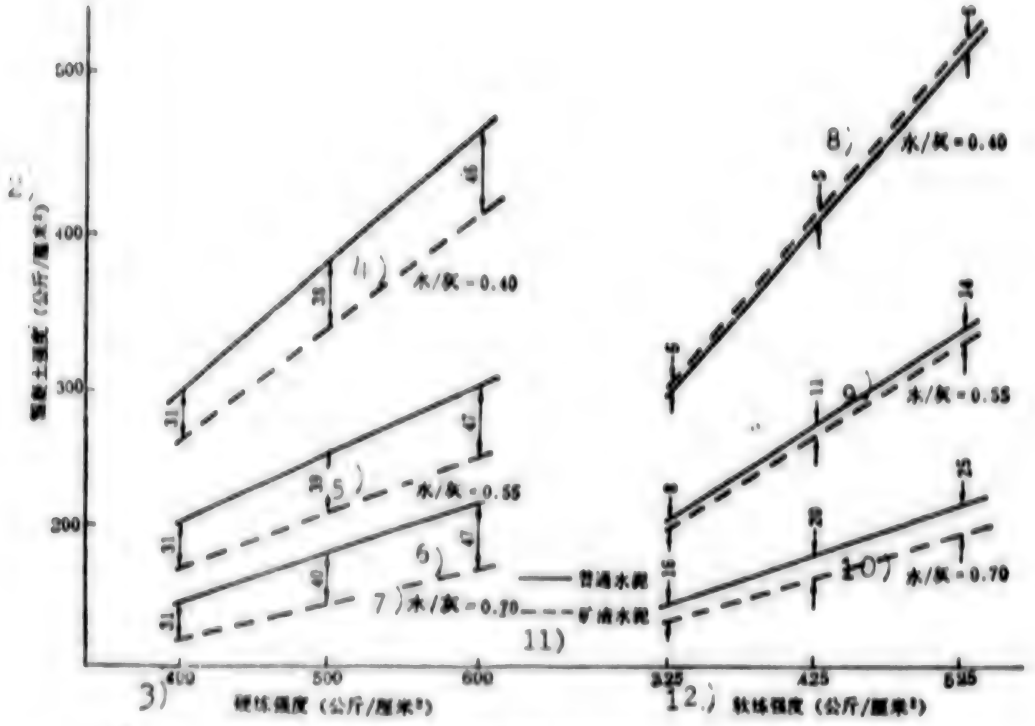
1) 混凝土类别	2) 水泥品种及龄期	3) 试验方法	4) 经验公式	n	γ	$\bar{V}$ (%)
5) 碎石混凝土	7) 普、矿合并 28天	8) 塑性	9) $R_{混凝土}=0.514R_{水泥}$(灰/水 0.575)	135	0.948	8.28
		11) 干硬性	$R_{混凝土}=0.401R_{水泥}$(灰/水 0.571)	135	0.938	10.25
6) 卵石混凝土	7) 普、矿合并 28天	8) 塑性	9) $R_{混凝土}=0.471R_{水泥}$(灰/水 0.563)	159	0.954	8.49
		11) 干硬性	$R_{混凝土}=0.371R_{水泥}$(灰/水 0.552)	159	0.933	11.18

Key:
1. Type concrete
2. Type and age of cement
3. Experimental method
4. Experimental Formula
5. Crushed stone
6. Pebble
7. Ordinary and slag combined
   28 days
8. Plastic mortar
9. concrete
10. plastic (lime/H_2O ..)
11. Earth-dry

Tables 11 and 12 show a comparison of changes in amounts of ordinary cement and slag cement used on the basis of the experimental formulae for plastic-mortar and earth-dry tested grades and for concrete grades. A look at the crushed rock concrete chart (Table 11) shows that when the same grades of concrete were made from the same earth-dry grades of slag cement and ordinary cement, about 9 percent more of the slag cement was required than of the ordinary cement. When a switch was made to plastic-mortar grading, the difference between the two was reduced to about 4 percent. A look at the pebble concrete (Table 12) shows that with the use of the same earth-dry test grades, between 8 and 13 percent more slag cement was needed than ordinary cement, but when a change was made to plastic mortar testing, the quantities of slag cement and ordinary cement were extremely close.

In short, once the new grades have gone into effect, slag cement will appear in a brand new light. When the grades are the same, slag and ordinary cement will give substantially the same grade of concrete. As a result of improved quality of slag cement, when new grades are used, a saving of between 4 and 9 percent can be made in the use of slag cement over the amount presently used.

Once the new grades have been put into effect, inasmuch as the quality of slag cement and ordinary cement is virtually identical, it is suggested that identical experimental formulae be used for both kinds of cement.



1) 图 16 同标号普通水泥与矿渣水泥配制的混凝土强度差别（卵石）

Key:
1. Figure 16. Differences in strength of concrete (pebbles) made from identical grades of ordinary cement and slag cement
2. Concrete strength (kilos/cm^2)
3. Earth-dry strength (kilos/cm^2)
4. water/lime = 0.40
5. water/lime - 0.50
6. ordinary cement
7. water/lime = 0.70
8. water/lime = 0.40
9. water/lime = 0.55
10. water/lime = 0.70
11. slag cement
12. plastic mortar strength (kilos/cm^2)

(1) 表 11 矿渣水泥、普通水泥配制同标号混凝土(碎石)时水泥用量(公斤/米³)比较

(2) 水泥标号	(3) 品种	(4) 混凝土标号			
		200°		300°	
(5) 600°级	(6) 矿渣	294	108.8%	388	109.0%
	(7) 普通	270	100%	356	100%
(8) 425°级	(9) 矿渣	273	103.9%	357	103.8%
	(10) 普通	263	100%	344	100%
(11) 400°级	(12) 矿渣	341	108.7%	460	109.4%
	(13) 普通	314	100%	420	100%
(14) 325°级	(15) 矿渣	324	103.8%	434	103.6%
	(16) 普通	312	100%	419	100%

Key:
1. Table 11. Comparative Amounts of Slag and Ordinary Cement Used to Make Identical Grades of Concrete (crushed stone) (kilos/m^3)
2. Cement grade
3. Type cement
4. Concrete grade
5. 500# earth dry
6. Slag
7. Ordinary
8. 425# plastic mortar
9. Slag
10. Ordinary
11. 400#
12. Slag
13. Ordinary
14. 325# plastic mortar
15. Slag
16. Ordinary

Applicable to crushed stone concrete made from either ordinary cement or slag cement:

$$R_{concrete} = 0.51R_{plastic\ mortar}\left(\frac{lime}{water} - 0.58\right)$$

Applicable to pebble concrete made from either ordinary cement or slag cement:

$$R_{concrete} = 0.47R_{plastic\ mortar}\left(\frac{lime}{water} - 0.56\right)$$

It must be pointed out that inasmuch as the amount of concrete work done so far has been limited and since representative samples have been insufficient, the above formulae are offered only to those interested for reference. Further research must be done in the future to get better accuracy.

1) 表 12 矿渣水泥、普通水泥配制同标号混凝土(卵石)时水泥用量(公斤/米³)比较

2) 水泥标号	3) 品种	4) 混凝土标号 200°		300°	
5) 500°硬	6) 矿渣	313	113.4%	410	110.2%
	7) 普通	276	100%	372	100%
8) 425°快	9) 矿渣	289	105.9%	374	101.3%
	10) 普通	273	100%	369	100%
11) 400°硬	12) 矿渣	362	111.8%	482	108.1%
	13) 普通	324	100%	446	100%
14) 325°快	15) 矿渣	341	102.8%	452	98.9
	16) 普通	332	100%	457	100%

17. 注：表11及表12单位用水量均按180公斤/米³计算。

Key: 1. Table 12. Comparative Amounts of Slag and Ordinary Cement Used To Make Identical Grades of Concrete (Pebbles) (kilos/m^3)

2. Cement grade
3. Type cement
4. Concrete grade
5. 500# earth dry
6. Slag
7. Ordinary
8. 425# plastic mortar
9. Slag
10. Ordinary
11. 400# earth dry
12. Slag
13. Ordinary
14. 325# plastic mortar
15. Slag
16. Ordinary
17. Note: In tables 11 and 12 average volume of water used per unit calculated at 180 kilograms per cubic meter.

6. Conclusion

Product technical standards provide a common technical foundation for the production and use of goods. This revision of cement standards, which was done primarily for the purpose of improving the quality of our country's cement products will, once they have been put into effect nationwide, have a major effect on producers, users, and researchers throughout the land.

The kinds of cement most frequently used in our country will expand from the original three to five. Portland cement to which no aggregates have been added will come to perform major service in our country wherever high strength, shock resistance, resistance to abrasion, and resistance to freezing are required; and it will create conditions for the development of the new technology of prestressed concrete and fiber-reinforced

concrete. While fly-ash cement will expand use of a waste product of power generating plants, it will better serve construction of massive water conservancy projects where low heat of hydration and high resistance to water are required.

With improvement in the highest grades of ordinary cement and slag cement, the construction sector will be able to make high grade concrete economically. More importantly, once a change is made to the use of the plastic mortar test grading, construction sites will be able to gage concrete grades accurately. More particularly, because of improvements in the quality of slag cement, so long as the grades are identical, different types of cement will produce substantially the same grade of concrete, thereby making it possible to assure project quality while saving on the volume of cement used and reducing the consumption of cement.

Once the new standards take effect, cement producers will have to make some improvements in existing production technology and technical conditions in order to satisfy demands for improved quality. They will have to realize that this effort is a process of improving management in enterprises, improving production techniques, and improving product quality. The liberalization of MgO criteria, which is part of the new standards will help numerous plants use their mineral resources more fully. More importantly, improvement in the various physical inspection methods that are part of the plastic mortar method will greatly conserve laboratory manpower and materials in the future, and will more effectively control production technology and product quality. It will be of particularly great help in assuring quality of product and improvement of product by the broad masses of large and small cement plants.

Where units involved in scientific research on cement formerly detoured around reforms to cement standards, they have now undertaken a lot of scientific experimentation and have made some accomplishments in the field. At the same time, however, they have found quite a few problems that require still further study to find a solution. For example, the reaction of aggregates in cement, ways of determining activeness of cement, and how to further expand selection of superior quality aggregates for use; further understanding of MgO, SO_3, CaO, and alkali content in their effects on various properties of cement; better mastery of the mechanics of swelling and shrinking in cement in order to assure stability of volume, as well as providing faster and handier methods for measuring more accurately the activeness and other properties of cement.

Revision of cement standards is a long-term task requiring scientific study. As industrial construction develops, standards will have to be constantly revised and improved. This revision of cement standards, though it has accomplished much, is still not perfect in many respects. We believe that after a period of experience, some new problems will show up. Consequently, we will henceforth be required to continue to strive in the three-way program of production, use and study.

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CRUISE MISSILE CHARACTERISTICS SURVEYED

Beijing HANGKONG ZHISHI [AERONAUTICAL KNOWLEDGE] in Chinese No 1, Jan 80 pp 12-14

[Article by Ni Xingqiang [0242 5887 1730]: "Cruise Missiles: A Survey"]

[Text] The World's First Cruise Missile

In the summer of 1944, when the flames of World War II had engulfed Europe, only England has escaped disaster, thanks to the broad English Channel. Many Englishmen felt themselves very lucky on this account.

But unexpectedly one evening, piercing air raid sirens suddenly sounded in London, the capital, and before the inhabitants had time to go to the air raid shelters the sound of a great explosion rang out throughout the city. The air defense soldiers rapidly turned on their searchlights, which like many snow-white jewels searched the pitch-black sky. But a long search found no enemy aircraft aloft.

But just where had this bomb which had hit London come from? The mystery was soon solved. A guided missile had crossed the broad English Channel and attacked the British capital. This missile-bomb developed by the Germans was the world's first cruise missile, the V-1, also called an aerodynamic missile. Externally it looked like an elongated eggplant, with the nose section containing a 1,000-kg charge. Its speed was 500-640 km/hr and the range was 350 km. Because of the poor capabilities of this missile, the limited range and low accuracy, it was easy to intercept. Because it had no guidance mechanism, even if it broke through the air defenses it was not likely to hit military targets. According to statistics, in 1944-1945 the Germans launched about 8,000 of these missiles against London, and only an estimated 30 percent reached their target area, with some being shot down and some going astray.

After the war, the United States and the Soviet Union both obtained information on the V-1 and continued research and development work along these lines. In the 1950's enthusiasm for developing cruise missiles such as

the Sidewinder, the tianshixing, douniushi and maxi, developed in the United States. Because of technical limitations at that time, the missiles had the defects of large size, low accuracy and poor penetration capability, so that at the beginning of the 1960's their development reached a standstill.

In the last decade or so, aviation and electronics technology have developed rapidly. Small-sized turbofan engines develop a kilogram of thrust while consuming 0.7 kh of fuel per hour, so that an engine developing 300 kg of thrust can have a diameter as small as 300 mm. Because cruise missiles must fly at a low level for several thousand kilometers, in addition to a large cumulative error in the inertial guidance system, engine malfunctions and natural factors such as wind have a major impact on accuracy. In order to guide the missile accurately toward its target, continuous corrections must be introduced into the inertial guidance system. The required equipment used to be extremely bulky and could not be used. But in recent years development of microcomputers and microprocessors has made it possible to produce small and very accurate guidance systems for cruise missiles, so that since the early 1970's interest has again been directed toward their development. The new generation of cruise missiles have the advantages of high penetration capability and survivability, good maneuverability and concealability, low cost, and capability for employment by all three services, and accordingly they are now gaining favor worldwide.

Air-Launched, Sea-Launched and Ground-Launched Cruise Missiles

Currently the United States is developing three cruise missiles: the air-launched cruise missile (ALCM), the sea-launched cruise missile (SLCM) and the ground-launched cruise missile (GLCM). Below we give a brief introduction to the three types.

The ALCM was developed by Boeing for the U.S. Air Force. Designated the AGM-86A, it could be launched from rotating launch racks in a B-52 bomber. Because of constraint by the launch racks, there were difficulties with its construction. Its range is 1,300 km. In order to increase the range, the AGM-86B was developed from the AGM-86A (primarily by adding an auxiliary fuel tank to the body). This missile has a range of 2,400 km but it cannot use the original rotating launch racks, but could be carried only under the wings of the B-52. Later an updated AGM-86B was developed which could be launched from the racks. Eight AGM-86A or AGM-86B missiles can be carried in the launch racks in the body of a B-52, and 12 can be carried under the wings; the capabilities are shown in the table.

The launch procedure for this cruise missile is shown in the diagram inside the back cover [not reproduced]. Some 0.1 seconds after the missile leaves the launch rack, the engine air intake retracted into the body of the missile springs up from it. After 0.13 seconds the control surfaces which have been folded back are extended. After 0.28 seconds the extension is complete.

Then the elevons begin to control the missile in order to prevent it from pitching upward and colliding with the launch aircraft. After about 0.25 seconds the vertical tail section extends, and after 0.48 seconds it is completely extended, stabilizing the missile's flight. After 0.5 seconds the turbofan engine starts, reaching full thrust in 5-10 seconds depending on the launch altitude. A full second after the missile leaves the launch rack, and another actuating igniter triggers, extending the folded wings of the missile, which reach full extension after 2 seconds, at which time the cruise missile is already some distance from the launch aircraft.

The SLCM, named the Tomahawk by the U.S. Navy and designated the YBGM-109 and YBGM-110, is launched from a submerged submarine through standard torpedo tubes. In April 1976, the YBGM-109 won a competition. Its maximum range is 3,200 km. Currently it has already been decided to develop an air-launched Tomahawk from this model to compete with the AGM-86, and its use as a missile launched from surface ships and land vehicles is also being considered. In order to allow for this triple capability, it must be developed by the "building block method." Its capabilities are shown in the table. The Harpoon missile, shown in the inside back cover [not reproduced] is a United States antiship missile, and the Tomahawk tactical model was developed from it.

The submerged launch procedure is as follows. First a well-protected missile is inserted directly into a torpedo tube, which is then filled with water, and an MK-117 fire control system is used to check out the missile and to adjust its guidance system, all of which takes about 20 minutes. Next the submarine's hydraulic launch system ejects the cruise missile from the torpedo tube, trailing a line about 12.2 meters long. When there is a pull on this line, the safety interlock system triggers and the booster ignites. The submerged missile is accelerated forward by the booster, and by control of the direction of thrust it is made to turn upward from the horizontal position of the submarine toward the surface of the water; a steady climb is assured. When the missile reaches the surface, it emerges at a certain angle. A small igniter goes into action, blowing off a cover on the tail of the missile and extending the tail fins. The engine air intake cover is also jettisoned. After the tail fins have extended, they keep the missile from rolling, and elevation and heading commands are issued so that the missile rises on a specified trajectory. Then the booster engine is jettisoned and wings are extended by means of springs, and after a short time the turbofan engine goes into action. When the missile reaches the highest point of its trajectory, the turbofan engine has reached full thrust. After reaching the top of its trajectory the missile begins to descend, coming down to about 15 meters above the sea surface and beginning its cruise stage.

The GLCM was developed from the Tomahawk. A truck is used as the launch platform. On the truck are 4 launch racks, with the missiles packed in the same launch containers as for shipboard use, and generally carried on the truck. At launch time a hydraulic cylinder raises the missile

to a specified launch elevation and launches it just as on shipboard. Each cruise missile launcher detachment has four launch vehicles.

The launch procedure is as follows. First the hydraulic cylinder raises four launch containers to the specified elevation. The launch control system enters the necessary guidance data into the guidance system and adjusts the guidance system. Next the booster ignites and the missile is fired from the launch container. When the missile has traveled about 300 meters, its tail extends, the engine air intake springs open, and after about 800 meters' flight the wings are extended. After about 1,200 meters the booster is jettisoned and the main engine soon ignites. After about 2,000 meters the missile reaches the top of the launch trajectory (about 300 meters high), after which it descends to its cruising altitude.

How Do the Three Cruise Missiles Accomplish Their Combat Mission?

Although the three missiles described above differ in their launch stage, they behave identically when they enter the cruise stage. Many different flight profiles can be chosen.

In one flight profile, after conclusion of the initial launch stage the cruise missile descends nearly to the sea surface (generally about 15 meters above it), but when it comes overland it flies at an altitude of about 50 meters. This is the main flight profile, and it is difficult to detect or intercept, so that penetrability is high.

Another profile is flight at a relatively high altitude (about 3,000 meters) after completion of the launch stage, with descent to a low altitude only when approaching the target. This flight profile is easier to detect and intercept, so that it is generally not used when attacking inland targets.

The third profile is a high trajectory when over the sea, switching to a low trajectory when overland. This is a typical flight profile with the advantages of the two previously mentioned types.

Before launching the cruise missile, the topography and surface characteristics of the area in question, which have been reconnoitered in advance, are stored in the onboard computer along with the flight path. After the launch, the missile first reaches the maximum altitude, then begins the cruise stage. While in the cruise stage, the missile uses a combination of inertial guidance and terrain comparison correction, employing an altimeter for control of flight altitude. While flying over the sea before entering the enemy's territory, inertial guidance must be used. When the missile flies in overland and first senses the land, it uses terrain comparison to make an initial correction of its flight path, then returns to use of its inertial guidance, making another correction by means of terrain comparison after flying some distance. By repeating this process it ultimately flies to its target. When it enters the target area, in order to hit its target

more accurately, it switches to guidance by an image comparison system, and can arrive at its target with an accuracy within about 30 meters. Currently the United States is developing a global statellite positioning system to control flight paths, and this will increase accuracy to within about 10 meters. For example, the missile first follows the rise and fall of the terrain, then in order to avoid detection by the enemy it skirts a city, after which it flies around some hills for the purpose of concealment, then enters an area where terrain changes are relatively complex. Here it uses the complex reflections from broken terrain to confuse enemy detection. Then the missile reaches a defended area in front of the target, and in order to avoid being shot down by enemy air defenses it selects a path between two air defense areas for its flight to the target. In the final attack stage, the missile may choose to attack its target head on, from the side or from the rear so as to catch the target by surprise and defeat the enemy. Because cruise missiles can be launched in large numbers, the enemy cannot defend against them, which increases the threat (Fig. 2).

Cruise Missiles of the Future

Current cruise missiles are all subsonic types propelled by turbofan engines, with speeds of Mach 0.6-0.85. Compared with advanced fighters, this is clearly a very low speed. Analysis indicates that the reason why current cruise missiles have relatively good penetration capabilities is primarily their extremely low flight altitude and small radar profile, which prevents the enemy from detecting them. But if it became possible to detect and track them, they could be defended against. Accordingly, people have suggested developing supersonic cruise missiles with a rocket-ramjet propulsion system. In reality, the United States Air Force has already begun developing a supersonic cruise missile, known as the "Advanced Strategic Air-Launched Missile" (ASALM). This missile is already in the competitive development stage.

The ASALM is a next-generation supersonic cruise missile with a range of about 320 km which can be launched at low altitude and fly either high or low.

Some people believe that the next generation of cruise missiles will not be supersonic but will still be subsonic low-altitude missiles. The ASALM cannot fly very low, so that it may be detected early, which decreases its penetration capability and makes it unsuitable for use as a long-range cruise missile. But because supersonic cruise missiles move very fast, within a range of several hundred kilometers they have the advantage of speed and short reaction time.

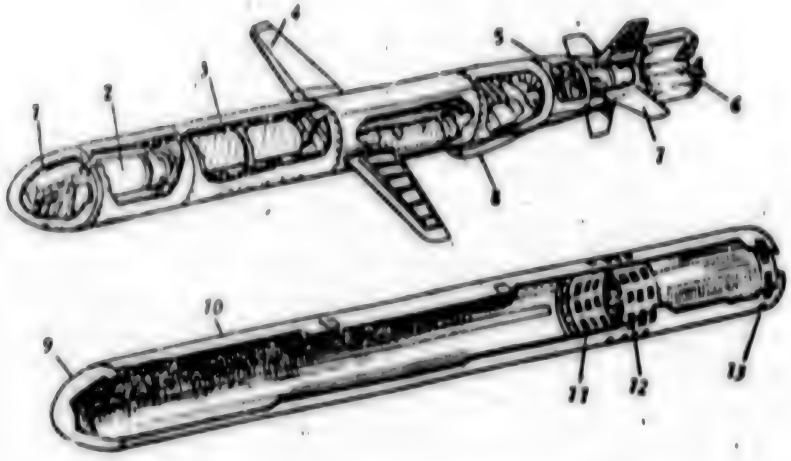

Fig. 1. The YBGM Tomahawk cruise missile

Key:
1. Guidance system
2. Nuclear warhead
3. Fuel air clearance pocket
4. Folding wings
5. Turbofan engine
6. Solid-fuel booster
7. Folding tail fins
8. Retractible air intake
9. Nose cover
10. Launcher
11. Sleeve
12. Forward flow slots
13. Rear flow slots

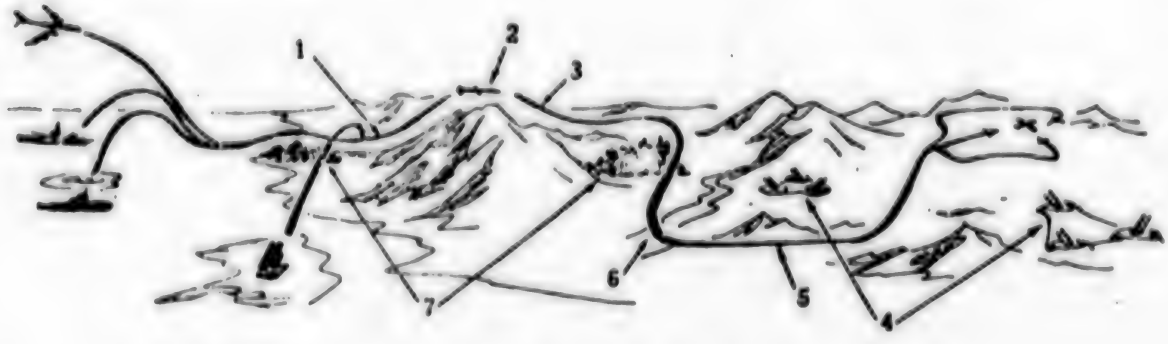

Fig 2. Cruise missile flight path

Key:
1. Terrain tracking
2. Long-range infrared and radar tracking signal
3. Low-altitude flight profile (50 m)
4. Evasion of defenses
5. Returning waves from surface irregularities
6. Terrain avoidance
7. Terrain comparison

Table.

Name	Length (m)	Diameter (m)	Wing-Span (m)	Launch Weight (kg)	Range (km)	Cruise Speed
V-1	7.6	0.83	5.3	2,750	350	0.5 M
Sidewinder	13.2			6,300	9000	0.9 M
Harpoon AGM-84A	4.58	0.343	0.918	667	110	0.85M
AGM-86B	3.657		3.657	1,270	2400	0.6-0.85 M
YBGM-109 (strategic version)	6.40	0.517	2.54	1,360	97-3200	0.7-0.85 M

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CSO: 4008

INERTIAL GUIDANCE, ATTACK SYSTEM DESCRIBED

Beijing HANGKONG ZHISHI [AERONAUTICAL KNOWLEDGE] in Chinese No 1, Jan 80 pp 15-17

[Article by Xu Guozhen [6079 0948 4394]: "Fighter Inertial Guidance and Attack Systems"]

[Text] The guidance and attack system uses accurate initial position, attitude and speed signals furnished by the inertial guidance system as the signal source for a fighter's fire control system, thus increasing the accuracy and effectiveness of cannon, air-to-air missiles and air-to-ground missiles, and in addition performs fighter guidance functions.

In October 1973, when the fourth Mideast War broke out, the Israeli Air Force, piloting American-made fighter-bombers, provided air support to the advancing Israeli Army. The Egyptians used high-altitude air defense missiles, medium-altitude air defense missiles and special missiles for dealing with medium and low altitude aircraft, as well as light, maneuverable man-portable surface-to-air missiles. It was because the Egyptians had this complete missile system that they were able to thwart the Israeli Air Force's air support plans. This posed an extremely grave problem for the ground attack mission: faced with so formidable an air defense missile system, what tactics should ground attack fighters use?

Low-Altitude Penetration Tactics

Clearly, at present when air defense capabilities are increasing constantly, in order to penetrate enemy lines with heavily concentrated firepower in the high, middle and low altitude zones, the attacking planes require an advance in tactics and technology. This means they must find a method of destroying the enemy before he discovers them and counterattacks. Some defense research organizations in Western Europe believe that an effective method of achieving this goal is to carry out low altitude surprise attacks from 60-600 meters.

In terms of defeating air defenses this is feasible. The detection range of ground-based radar is limited, and it cannot detect objects in hilly terrain surrounding it, so that by flying low and taking advantage of the radar dead area below the horizontal it is possible to avoid radar detection. From the attack standpoint it is also feasible. As everyone knows, only by causing maximum destruction to the enemy is it possible to protect oneself effectively, so that only by surprise tactics and the ability to attack a target accurately on a single pass is it possible to carry out and complete an attack mission and preserve one's own targets.

The West and the Soviet Union will continue competing in the developing of low altitude ground attack aircraft capable of surprise attack. Because of the demands of low altitude flight, the aircraft must be equipped with an accurate flight control and guidance system as well as a powerful fire control system. For example, the main United States ground attack plane is the A-10. It was designed primarily to combat Soviet armored units with strong air defense protection in the European theater, and it was required to be able to destroy 11 tanks in one sortie. The Su-19 is a soviet fighter-bomber developed in recent years which has a low-altitude long-range attack capability and is the main Soviet front-line ground-attack fighter.

Employment of the Inertial Guidance/Attack System of Ground Attack Fighters

When an attack plane is flying at a low altitude, the burden on the pilot is a heavy one, since he must concentrate on avoiding crashing and also must prepare to attack at any time, which means that while flying the pilot must keep track of both guidance and his weapons. Because of this requirement the guidance must be simple, automatic and accurate, and the important signals must be effective and clearly displayed, while handling of the weapon systems must be simple and accurate and target position must be accurately usable for direct attack and must give the pilot the maximum freedom for maneuver and evasion.

The only way to meet these both strict and comprehensive demands is to rely on complex and accurate electronic equipment.

In order to increase the precision of low altitude guidance and employment of armaments, current ground attack aircraft generally use a heads-up display system connected to the guidance system (i.e. the guidance-attack system) to replace traditional gyroscopic sighting systems. Different configurations include an inertial guidance/attack system, a doppler correlation system, an atmospheric data system and the like, with the accuracy of the inertial guidance-attack system being the highest. For example, to destroy a ground target, if we take the number of sorties required by a simple aircraft equipped with a gyroscopic sight as 100 percent, the number of sorties for aircraft equipped with a doppler/attitude-direction reference system is 80 percent, that for an aircraft equipped only with an inertial guidance system is 50 percent, and that for one equipped with an inertial guidance-attack system can be decreased to 25 percent.

Figs. 2 and 3 give a further indication of the superiority of the inertial guidance-attack system in terms of target engagement and attack probabilities and number of sorties required to carry out a given attack.

Why is the accuracy of the inertial guidance-attack system greater than that of all the others? This is inseparable from the operating principles of inertial guidance. Everyone knows that what we call inertial guidance involves sensing the acceleration of a moving object, calculating the speed, position and other data and carrying out the technical measures for guidance. Accordingly, it can very reliably and accurately reflect the motion of a maneuvering aircraft, which is what is needed in a weapon sighting system. Accurate weapon firing requires accurate determination of the aircraft's position and that of the target, and firing error is primarily governed by speed and attitude error; the inertial guidance system can provide an attitude signal while the aircraft is maneuvering which is more accurate than that provided by any other attitude instrument. It is also a valuable speed sensor, so that it can both insure accurate launching of onboard rockets and provide the cannon sighting system with the various signals it needs can be combined with the display to produce a "hot line" fast sighting system, and can be combined with a radio altimeter to provide the bomb release system with accurate altitude, drift and vertical velocity signals and the like. Moreover, the guidance-attack system gives the aircraft complete position direction coordinates relative to its target's movement and position, so that the aircraft does not necessarily need to start its attack on a "predetermined" profile, which increases the aircraft's chances of carrying out the attack and gives it an excellent ground attack capability. Moreover, because it is automatically guided, and independent of external equipment, the system is difficult for the enemy to detect and interfere with, so that the aircraft can carry out its attack with sufficient maneuverability and surprise. Clearly if a ground attack fighter has an inertial guidance-attack system this not only increases its guidance capabilities but during a difficult attack it can destroy a target, whose position coordinates are already known, on one pass with minimal exposure. This in turn means a decrease in the number of sorties required to destroy a specified target and decrease the damage rate for the attacking aircraft.

Future Prospects for Employment of Inertial Guidance-Attack Systems

The guidance-attack system generally consists of: an inertial guidance component, a digital computer, a display and a laser rangefinder or radar. Of these, the inertial guidance components are the main signal source of the system, so that they are the basis of system selection. Currently, inertial guidance-attack systems generally have the following characteristics: guidance accuracy 1 nautical mile per hour, average time between malfunctions several hundred hours, speed alinement time 2 minutes, weapon firing system error less than 6 milliradians. On a typical attack profile, this accuracy leads to a 50 percent bomb hit probability within 20 meters.

In recent years a tendency has appeared in Europe to retrofit older aircraft with modern electronic equipment. When an older aircraft is retrofitted with new electronic equipment, generally some guidance-attack system, its attack capabilities can be greatly increased, and expense is decreased, and material-technical support and training time are accordingly decreased. Large amounts of target practice indicate that this retrofitting program is feasible and it is claimed that use of inertial guidance-attack systems to modernize aircraft inventories makes them equivalent to new inventories. One reason that Europe is using this technical approach to improving its fighters is that currently the Warsaw Pact has a 2.3:1 superiority over NATO in number of warplanes. With equipment modernization, by replacing old aircraft with relatively fewer but more capable aircraft, it will be possible to decrease the number of airplanes steadily. Accordingly, equipping ground attack fighters with inertial guidance-attack systems appears to be a practicable approach. Currently this retrofitting is not only being carried out in Europe but is being tested by Egypt and Israel in the Mideast and by Japan and India.

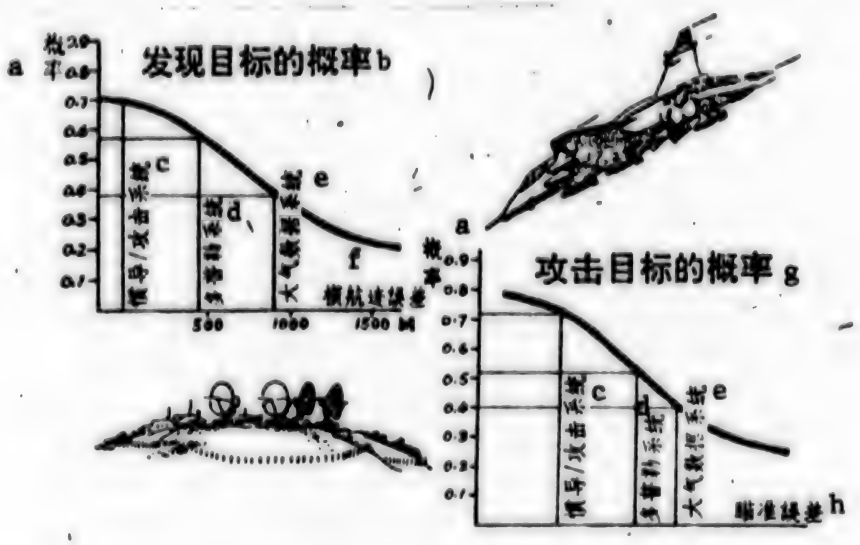

Fig. 2. Some comparisons of the accuracy of guidance-attack systems.

Key:

a. Probability
b. Target detection probability
c. Inertial guidance-attack system
d. Doppler system
e. Atmospheric data system
f. Tracking error, transverse flight
g. Target engagement probability
h. Sighting error

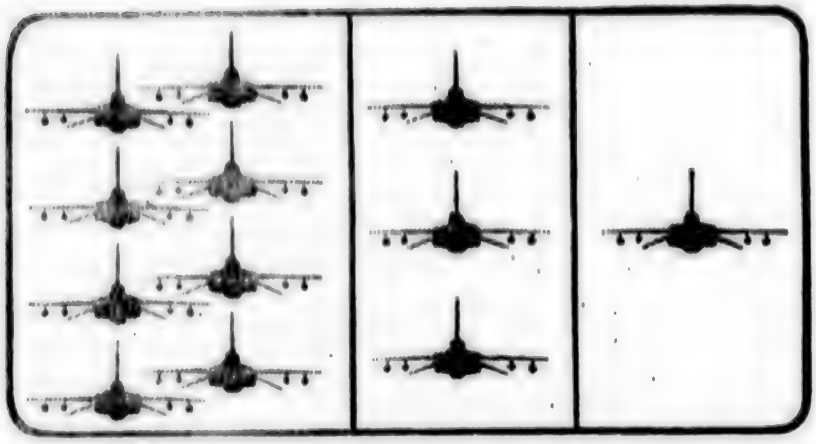

Fig. 3. Comparison of number of sorties needed to kill a given target

Left: Aircraft with atmospheric data system
Center: Aircraft with doppler correlation system;
Right: Aircraft with inertial guidance-attack system.

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'RENMIN RIBAO' COMMENTS ON GEOLOGY WORK

HK070329 Beijing RENMIN RIBAO in Chinese 15 Mar 80 p 2 HK

[Article by commentator: "Geology Work Must Lay a Good Foundation for the Four Modernizations"]

[Text] We have often said that our country is vast in area and possesses abundant resources. Geological survey has shown that our mineral resources are extremely rich. The importance of geology work is becoming ever more prominent in the wake of the development of economic construction. In drawing up a long-term plan for national construction, we must first get a clear idea of our mineral resources; to develop agriculture and animal husbandry, we must first get a clear idea of underground water resources; to speed up petroleum exploitation, we must first provide oilfield prospecting and exploitation bases. In short, the data provoided by the geological departments has a direct bearing on the speed and scale of modernization. Hence we should put geology work in a primary, basic and strategic position in accordance with the needs of the Four Modernizations. However, judging by present conditions, geology work is in fact a weak link.

Encouraging results have been achieved in geology work since its central tasks were defined as geology and prospering for minerals. China has already proved reserves of 130 minerals and has become one of the few countries with a relatively full range of minerals. Outstanding achievements have been scored in petroleum prospecting, and a number of important successes have been gained in surveying solid minerals, hydrological geology work has been strengthened in commodity grain bases and low-yielding areas, and a number of new water sources have been found in pastoral areas short of water in Nei Mongol, Xinjiang and Gansu. Although great successes have been achieved in geology work, they are very far from meeting the needs of building the Four Modernizations. It will be necessary to do a lot of hard work to change this situation. Unless geology work is improved in the next few years, it will lag ever further behind when still greater development has been achieved in the national economy after the next few years.

In planning geology work, it is necessary to act in accordance with the laws of geology, pay attention to economic rationality, stress economic results and correctly understand and handle the relationship between the aims and the methods of geology. Through carrying out readjustment in

geology work, we should gradually change the failure of geological task planning to conform to objective geological conditions, the uneven distribution of minerals in the earth's crust is a fundamental objective law of geology, and if we violate it we will make mistakes. Leadership at all levels must not issue blind commands divorced from geological conditions.

Restructuring is an important content of the eight-character principle, There are very many defects in the current management systems and methods in the geology system, and restructuring is required. The restructuring work will be affected by the force of habit, and efforts must be made to solve this problem. In the whole country 21 geology teams in 10 provinces have carried out division of work according to specialities and established separate teams for geology work and mineral prospecting, and institutions have put into effect enterprise management and set up trial points for the contract system. Initial results have already been gained in some of these. We must now sum up experiences and further expand the scope of trial points in restructuring work: At the same time we should gradually break down the old convention of establishing teams according to administrative regions, and establish them according to prospective mineral regions or belts. It is also necessary to set up a corresponding rear area life and establish research bases. Cadres at all levels must strive to learn specialized knowledge, institute scientific management of geology work, and further expand enterprise self-management rights.

The geology departments must do well in readjusting the leadership groups at all levels. Technical experts and persons familiar with professional work must account for one third of the members of these groups within a few years. Leadership at all levels must carry forward the party's fine traditions and work style of political work, improve work methods, and truly center ideological and political work on geology and mineral prospecting work. It is necessary to strengthen education for the masses and overcome the anarchism, extreme individualism and lack of organization and discipline among a few people, to insure that the staff and workers will strengthen their sense of honor and responsibility in engaging in geology work and embrace the pioneering spirit of arduous struggle and difficulties. Collectives and individuals who score outstanding successes in geology and mineral prospecting should be commended and rewarded, as geology personnel do long periods of fieldwork and live a hard life. Their arduous pioneering spirit is worthy of emulation and their hard work should be respected by society. The geology staff and workers should learn from Li Siguang and from heroic and model figures. Learning their sense of the cause, it is necessary to rely on this spirit in national construction.

It is also necessary to have the close cooperation of all departments concerned in order to strengthen the weak link of geology. The geological departments are mainly responsible for geology work, and the coal, petroleum, metallurgical, building materials, and chemical industry departments and so on also possess specialized geology forces. Everyone should share out

the work and cooperate with each others, achieve coordinated development, and bring into full play the initiative of the comprehensive and the specialized geology departments in promoting geology work. The great majority of mineral deposits in China contain many useful elements. Geology staff and workers should expand the breadth of their knowledge, eswtablish the concept of the overall situation, institute comprehensive mineral prospecting, surveying and evaluating, and avoid duplication in work and waste of resources. It is necessary to regard the protection and rational exploitation of mineral resources as an important state technical and economic policy, and strictly ban sabotage of national resources by reckless exploitation. The relationship between geology work and the rural areas is extremely close, and the rural party committees at all levels and the masses must care for and support the work of the geology teams.

Abundant mineral resources constitute an important condition for accomplishing the Four Modernizations, and the party and state pin tremendous hopes on geology work. The geology workers must continue to display the pioneering spirit of arduous struggle amid difficulties and do still better at discovering abundant mineral resources and providing reliable geological data for the Four Modernizations.

CSO: 4020

LIFE SCIENCES

PATHOLOGY PROFESSOR ENCOURAGES USE OF IMPORTED TECHNICAL EQUIPMENT

Beijing GUANGMING RIBAO in Chinese 4 Feb 80 p 2

[Article by Wang Zhenling [3769 2182 1545], Lu Shiji [7627 1102 3444], and Lin Yutang [5677 3768 1016]: "Professor Li Wenzhen [2621 2429 6966] of the Hebei College of Medicine Bravely Took Up a Heavy Burden: Allowed the Introduction of Technological Equipment To Fully Produce a Good Result"]

[Text] A professor of pathology at the Hebei College of Medicine and deputy director of the Institute for Basic Medical Research, Li Wenzhen, has contributed to bringing imported technological equipment into full play and so recently has been judged a labor model for the whole country.

In 1975, the Hebei College of Medicine imported one modernized Model H500 electron microscope from Japan and responsibility for developing this kind of work was given to Comrade Li Wenzhen. Professor Li Wenzhen previously had devoted himself to research in pathology. In order to be able to handle the technology for the measurement, installation, and operation of this apparatus as soon as possible, he went successively to Beijing and Dongbei to study electron microscopy. During the day he practiced techniques of operation with his comrades, while in the evening he compiled related materials, translating altogether several hundred thousand characters of useful instructions, carefully arranging materials about the basic principles of the measurement equipment and the methods for calculating values. After the official use of the electron microscope, Li Wenzhen having completed an experiment would frequently work overtime, giving up many of his days off.

On one occasion, the Langfang Ward Hospital hoped to use the electron microscope to determine the mass of a man-made cell. At that time although Li Wenzhen was editing his book, he put down his own work and together with his comrades of the Electron Microscope Laboratory worked throughout the night to carry out the determination and to make up an illustration.

In order to cultivate a team skilled in experimental techniques using the electron microscope, Li Wenzhen often explained information about and techniques of electron microscopy to middle-aged and young scientific personnel, teaching the basic technological principles for making and preparing samples, helping them decide on research topics, and also personnally

helping middle-aged and young scientists prepare research papers. Under Professor Li Wenzhen's ardent cultivation, among the seven scientists of the Electron Microscope Laboratory, three young scientists already are able to make observations using the electron microscope and have, moreover, published articles in national medical journals. Li Wenzhen also has fastened over ten electron microscope technical cadres in related units.

At the same time as he was engaged in this electron microscope work, Professor Li Wenzhen also carried out responsibilities for teaching Chinese medicine in the Medical Department of his own college and pathology on branch campuses. His emphasis on spreading knowledge of electron microscopy into educational circles is a true contribution to raising the quality of education.

9504
CSO: 4008

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

GEOGRAPHICAL SOCIETIES HOLD CONGRESSES

China Geography Society

Beijing GUANGMING RIBAO in Chinese 20 Mar 80 p 2

[Text] To commemorate the 70th year of its founding and to review its accomplishments in the field of geography over the past 30 years, the Chinese Geography Society convened its fourth congress in Canton and held related academic seminars.

More than 300 geographers from all over the country assembled in a joyous mood to discuss plans on the four modernizations. Based on their knowledge in rationally developing the country's natural resources and their endeavors to maximize the utility of the superior geographical environments of our country, these delegates made some important suggestions to pertinent government departments.

The convention, which received close to 1000 papers, was the most productive of all previous geographical meetings. Active discussions were held on the future trends and tasks of geography. Among the participants were well-known geographers including Huang Bingwei [7906 4426 4850], Li Xudan [2621 2485 2481], Wu Chuanjun [0702 0278 6874], Zuo Dakang [1563 1129 1660], Li Chunfen [2621 2504 5358], Chen Shupeng [7115 6615 1756], and our young geographical worker Lin Bingyao [2651 3521 3613]. The papers they presented include: "Research on the Physical Geography of China," "Man-Land Relations and Human Geography," "Geography: Today and Tomorrow," "Future Trends and Tasks of Geography," and "The Application of Multivariate Analysis and Systems Engineering in Geography." The papers generated much enthusiasm among the participants.

Last year, the China Geography Society invited the Taiwan Geography Society to participate in a convention on the mainland. During the election of members to the board of directors, reservations were made for delegates from Tawian Province. This indicates the mainland's concern for geography professionals in Taiwan as well as its close cultural affinities with that province. Professor Chiao-min Hsieh of Pittsburgh University and Professor Yu Li of Colorado University of the United States were invited by the society to present papers at the convention.

During the meetings, Mr Huang Bingwei [7806 4426 4850] director of the Institute of Geography, Chinese Academy of Sciences, was democratically elected chairman of the board of directors of the China Geography Society.

Jiangsu Geography Society

Beijing DILI ZHISHI [Geographical Knowledge] in Chinese No 1, 1980 p 30

[Text] The Geography Society of Jiangsu Province held its third congress in Nanjing from October 1 to October 3 of 1979. There were 106 delegates in the convention, including invited delegates Zhu Binghai [2612 4426 3189], Guo Lingzhi [6753 0109 2535], Yao Zhensheng [1633 2650 3932], Zhi Chengxi [2457 2052 3556]. A total of 93 papers were received. These papers include: physical geography, development of drainage patterns, water resources management and environmental protection; and, economic geography, agricultural and industrial production, city planning, application of remote sensing techniques in the prediction of surface runoff and in the compilation of specialized maps, computerized mapping, quantitative geography, geography of place names, geography of tourism, and geographical education. All the above papers received a great deal of attention. Quite a few comrades maintained that the application of quantitative techniques and mathematical models is an important means in raising the standards of future geographical research. During the convention, 17 members were elected to the board of directors of the Geography Society of Jiangsu Province. Ren Meie [0117 5019 6948] was elected chairman of the board of directors; Zhou Lisan [0719 4539 0005], Zhang Tongzhu [1728 0681 6999], Li Xudan [2621 2485 2481], Wang Weiping [3769 4850 1456], and Qi Yannian [4359 1693 1628] were elected vice chairmen; Qi Yannian and Zhang Tongzhu were elected secretary general and deputy secretary general of the society respectively. The board of directors discussed the future tasks of the society and organized five specialty committees, namely, physical geography, economic geography, geomorphology, cartography and remote sensing, and geographical education, and a committee on the propagation of the science of geography.

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